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EVALUATION TESTING OF THERMOFIT SOLDER SLEEVES

Quality and Reliability Assurance Laboratory

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EVALUATION TESTING OF THERMOFIT SOLDER SLEEVES

ABSTRACT

This report contains data obtained during evaluation testing of thermofit solder sleeve D-101-31 when used on nickel clad copper wire and alloy 63 wire.

The tests performed include voltage drop, peel strength, dielectric strength, water immersion, moisture resistance, high temperature aging, and vibration. A test was conducted to determine the optimum heating time of the solder sleeve to obtain maximum peel strength of the joint. Another test, using additional flux, was performed to obtain better wetting of the shield. It was found that very good wetting of the connection was obtained when the shield braid was prefluxed; however, tests indicated that a corrosive flux residue remained in the connection. Voltage drop and peel strength tests of stub splices, a combination of crimp ferrules and solder sleeves, were included.

METHODS RESEARCH SECTION
APPLIED TECHNOLOGY BRANCH
ANALYTICAL OPERATIONS DIVISION

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SUMMARY

A literature research on thermofit solder sleeve shield terminations was made prior to performing this test program. The literature covered included various laboratory reports from Rayclad Tubes Incorporated and a Defense Documentation Center publication. See Appendix A, Reference Material List. During visual inspection of the specimens tested, it was found that strands of the shield protruded through the sleeve. This problem was reported in some of the literature that was researched. None of the reports surveyed covered the use of nickel wire in connection with solder sleeves. On the type of wire covered in the reports, solder sleeve connections test data indicate that this type of shield termination is as good or better than ferrule types. Data from voltage drop and peel strength tests, when performed according to the procedure given in MIL-F-21608A, indicates that the solder sleeve shield terminations specimens tested met the requirements of MIL-F-21608A. Only one specimen exhibited a shear pull strength which was less than required; 15 pounds for size 22 wire and 19 pounds for size 20 wire. The specimens peel pull tested cannot be compared to requirements of the above specifications because no parameters for this type of test are given.

The advantages of solder sleeve connections over crimp ferrule connections include less weight, smaller size, low resistance, high strength, and self-insulation.

Visual inspection of the specimens revealed that several specimens would be rejected for use because shield braid strands protruded through the sleeve. During wire preparation it is necessary to remove portions of shield braid. In doing so, extreme care should be exercised to insure that the strand lay is not disturbed and that the shield is cut off evenly. It is also very important that the lay of the shield braid strands is not disturbed while positioning the solder sleeve in place for heating, as disturbed strands may puncture and protrude through the sleeve during the application of heat.

SECTION I. INTRODUCTION

A. GENERAL

Shield termination solder connections, made by using Thermofit solder sleeves, were tested to evaluate the performance of these connections. All specimens tested were fabricated by the testing facility except as otherwise indicated.

Stub splices, fabricated by combining solder sleeves and crimp ferrules, were also tested for electrical integrity and peel strength.

B. THERMOFIT SOLDER SLEEVES

Thermofit solder sleeves are prepackaged, insulated solder joints which combine advantages of both solder joints and crimp type connections. This device is designed specifically for grounding shielded wire and joining hookup wire. However, since splicing of hookup wire is not generally allowed by MSFC, solder sleeves were only tested in connection with shield terminations.

The solder sleeve (figure 1) consists of an irradiated, heat-shrinkable, nonflammable, polyvinylidene sleeve containing a preform of fluxed solder at the center and a thermoplastic sealing ring in each end. When placed over a cable shield and briefly heated, the outer sleeve shrinks and the solder and thermoplastic melts, forming an insulated, encapsulated, solder termination (figure 2). This type of connection has the advantages of light weight, compactness, low resistance, and high strength. It is especially advantageous in RFI shielding, since the sleeve can be placed anywhere along the shield without cutting the shield. This also allows the connections to be staggered and results in a neater cable at the splice area.

C. TESTS PERFORMED

The tests performed were divided into six major groups as follows:

(1) Environmental Tests

(2) Peel Strength Tests

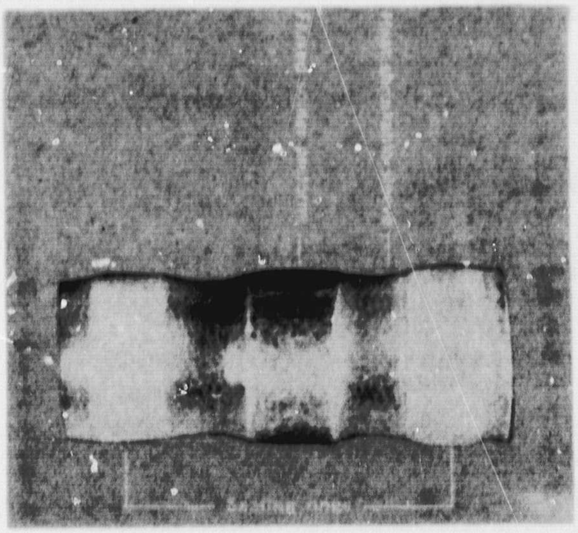


Figure 1. Thermofit Solder Sleeve

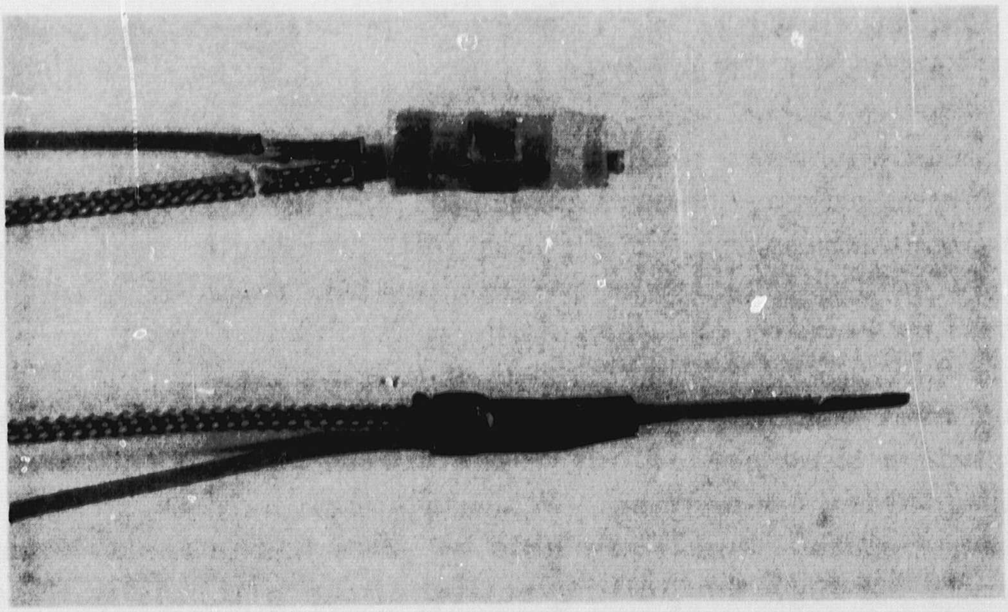


Figure 2. Fabrication of Shield Termination

(3) Flux Residue, Corrosion Test

(4) Dielectric Strength

(5) Voltage Drop and Pull Strength Tests*

(6) Fabrication Process

Tests performed under each of these groups are described in section III.

SECTION II. SPECIMEN FABRICATION

A. MATERIALS

Thermofit solder sleeves, Type D-101-31, were used in the fabrication of shield termination test specimens.

Except as otherwise indicated, conductor cables were composed of Surok insulated, size 20 AWG wire with a nickel-plated copper-braided shield. Ground leads (pigtails), except where otherwise indicated, were cut from Surok insulated, size 20 AWG, nickel-plated wire.

B. SPECIMEN CONFIGURATION

Specimens were made in two different configurations. Figure 3a shows a specimen prepared for a peel pull strength test. Figure 3b shows a specimen prepared for a shear pull strength test. In a peel test the specimen will be placed in the testing machine such that point a, figure 3a, will be held by one jaw of the machine and point b will be held by the other jaw. The pulling action of the jaws will cause the pigtail to bend back over the solder connection, and, as sufficient force is applied, the pigtail will be peeled out of the solder joint if the wire is stronger than the solder connection. When a specimen, as shown in figure 3b, is pull tested, points a and b are held by jaws of the tester, and if the wire is sufficiently strong, the pulling action of the machine will cause the pigtail to be pulled out of the solder connection. Usually a greater force is required to pull a shear pull connection to destruction than is required on the peel pull type.

*Specimens furnished by Manufacturing Engineering Laboratory.

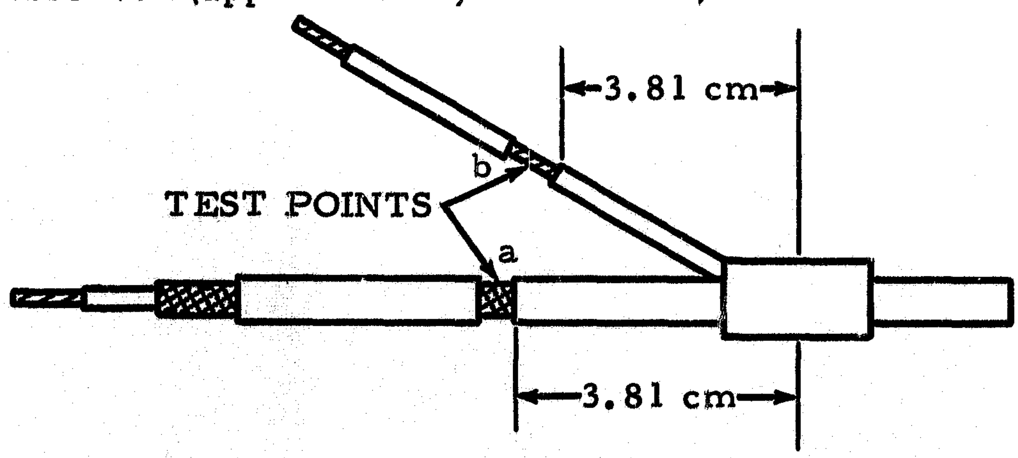
Conductor cables and ground leads were cut to various lengths of from 8.89 cm (3.5 inches) to 45.72 cm (18.0 inches), depending on the test requirements.

C. PREPARATION OF WIRE

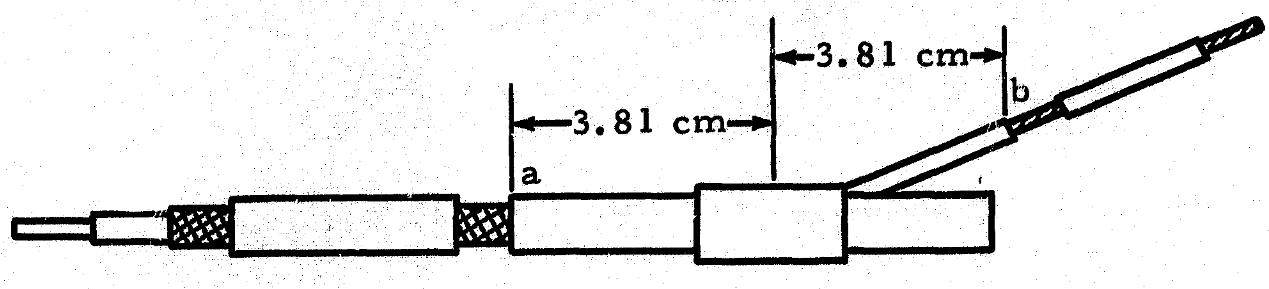
Conductor cable specimens were prepared by stripping approximately 18.91 cm (7.5 inches) of insulation from the shield and 12.7 cm (5.0 inches) of shield braid from one end, thus, leaving approximately 6.35 cm (2.5 inches) of shield braid exposed (figure 4). Ground leads were prepared by stripping approximately 6.35 cm (2.5 inches) of insulation from one end of the specimen and tinning the exposed conductor. Conductor preparation was accomplished by dipping the stripped conductor in Kester 1544 flux and tinning in accordance with NASA NPC 200-4. After tinning, flux residue was carefully washed off with ethyl alcohol.

D. SOLDERING PROCESS

The solder connection was made by heating the solder sleeve with a Rayclad Thermogun 500A equipped with a TG 14A reflector (figure 5). The gun was preheated until the temperature in the reflector stabilized at 315° ±3° C. The specimen was rotated in the hot air until solder flow was observed (approximately 16 seconds).

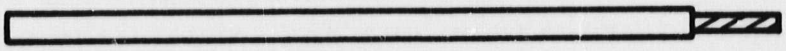


a. Prepared for Peel Pull



b. Prepared for Shear Pull

Figure 3. Specimen Configuration



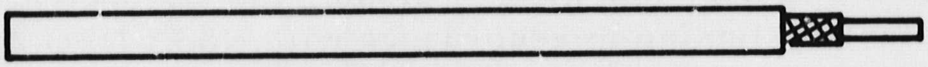


Figure 4. Material Preparation

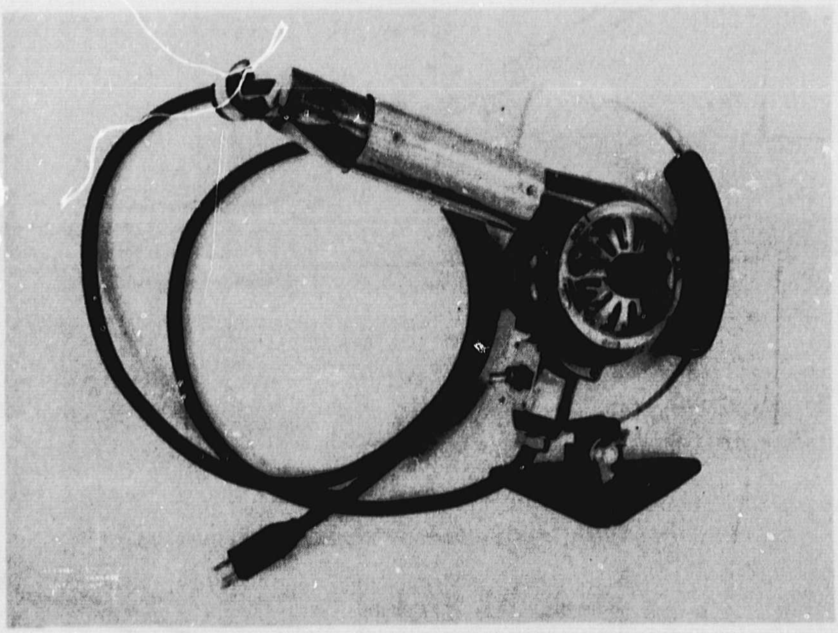


Figure 5. Thermogun 500A, With TG 14A Reflector

SECTION III. TESTING PROGRAM

A. GENERAL

This section covers the types of tests performed, purpose of tests, description of test specimens, test procedures, and test results. The part of the visual inspection concerning properly heated solder sleeves was based on information supplied by the vendor.

B. ENVIRONMENTAL TESTS

The following environmental tests were performed:

(1) Immersion Test No. 1

(2) Immersion Test No. 2

(3) Vibration Test

(4) High Temperature Test

(5) Moisture Resistance Test

1. Immersion Test No. 1.

a. Purpose. This test was performed to determine if solder sleeves form water tight insulation over solder connections.

b. Test specimen. Twenty-five test specimens were fabricated for this test in the configuration shown in figure 3a. Conductor cables were cut 10.16 cm (4.0 inches) long and the ground leads were cut 8.89 cm (3.5 inches) in length.

c. Test procedure. A visual inspection was made of each specimen prior to testing which included wicking of the solder along the shield, voids in the solder fillet, excessive discoloration about the joint, proper amount of heat as determined by comparison of the solder joint and figure 6, and shield strands protruding through the sleeve. A voltage drop test was made across the connection using specification MIL-F-21608A as a general guide to determine electrical integrity of the connection. Insulation was removed from the specimen as shown in

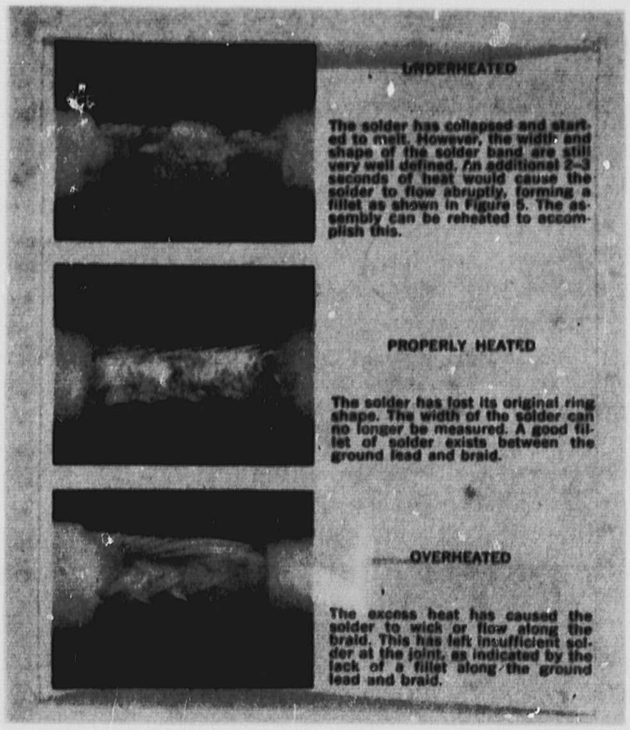


Figure 6. Visual Inspection Criteria

figure 3. After insulation was removed, test clips from a millivoltmeter were connected to the ground lead and the shield. A power source was connected to the end of the pigtail and the shield, and the voltage drop was measured while 1 ampere of current was flowing through the connection.

The immersion test was performed by suspending the specimens in a 5 percent salt solution (figure 7). The solder sleeve was immersed approximately 6.35 cm (2.5 inches) below the surface of the solution. On each specimen, an insulation resistance measurement was made between the pigtail and salt solution immediately after immersion.

After 24 hours of immersion, the insulation resistance measurements were repeated. The specimens were removed from the solution and the voltage drop test was repeated. Four specimens were chosen at random for sectioning. The remaining specimens were tested for peel strength.

d. Test results. Results of the visual inspection are given in table 1. (See appendix B for all tables.) No wicking or voids in the solder joint were observed.

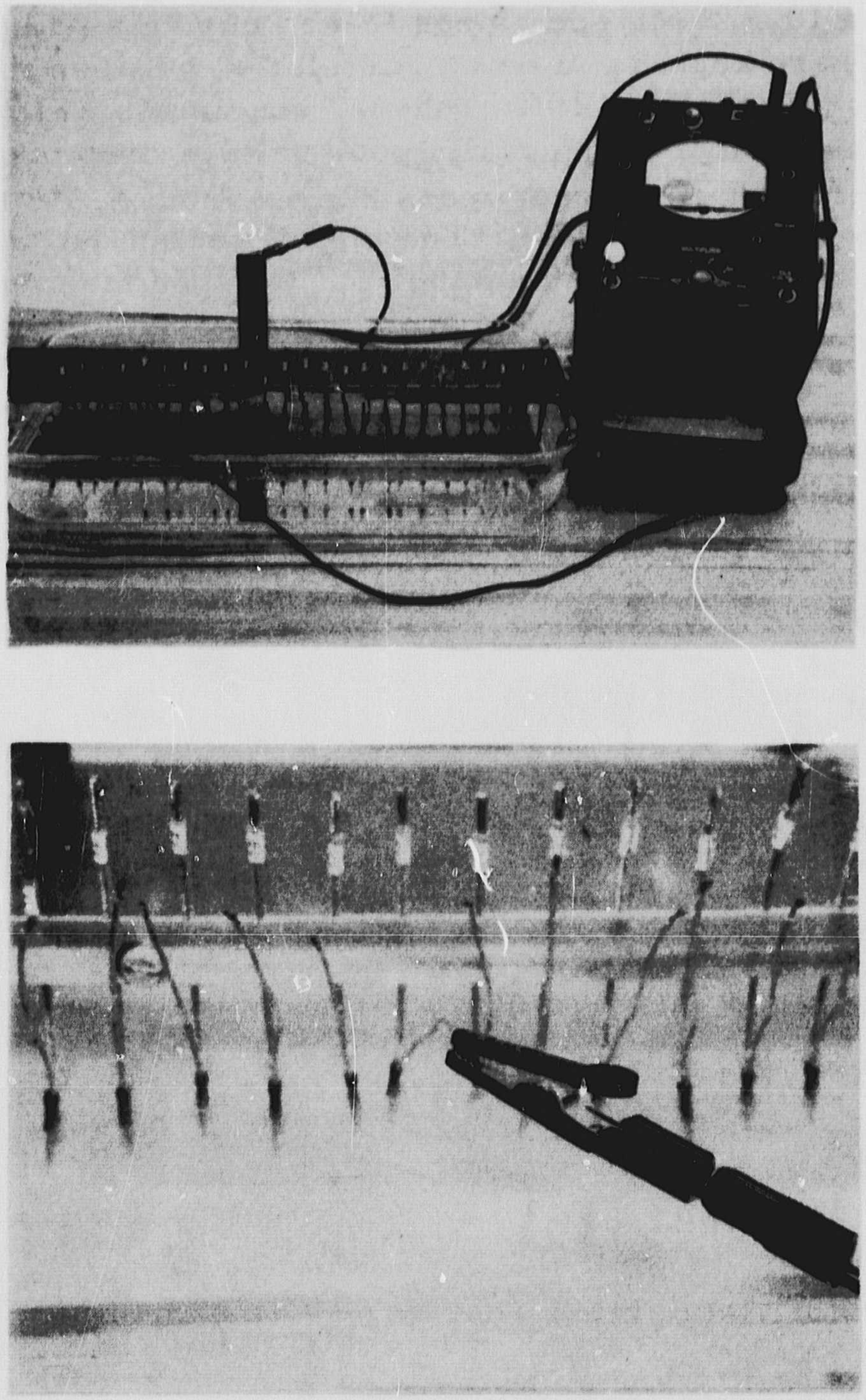


Figure 7. Immersion Test No. 1 Test Setup

The results of the tests performed are given in table 2. No significant changes in voltage drop were noted between initial and final readings, and all values exceeded the criteria of MIL-F-21608A. The insulation resistance tests of the specimens, while immersed in water, show that approximately half of the sleeves leaked water on initial immersion in the

salt solution and all but three specimens leaked during a 24 hour period of immersion. There appears to be no correlation between the visual inspection results and test results. That is, specimens which showed a defect (table 1) do not have an unusually poor voltage drop or pull strength (table 2). Peel strength of the specimens ranged from 6.353 kg (14 pounds) to 10.206 kg (22.5 pounds). The pigtail peeled out of the solder connection on all except specimen number 5. On specimen number 5, the braid pulled apart. Figure 8 shows a typical cross section of the specimens which were sectioned. Note that there is some solder flow around the braid; however, the voids in the braid indicate that complete wetting was not accomplished at the point of cross sectioning.

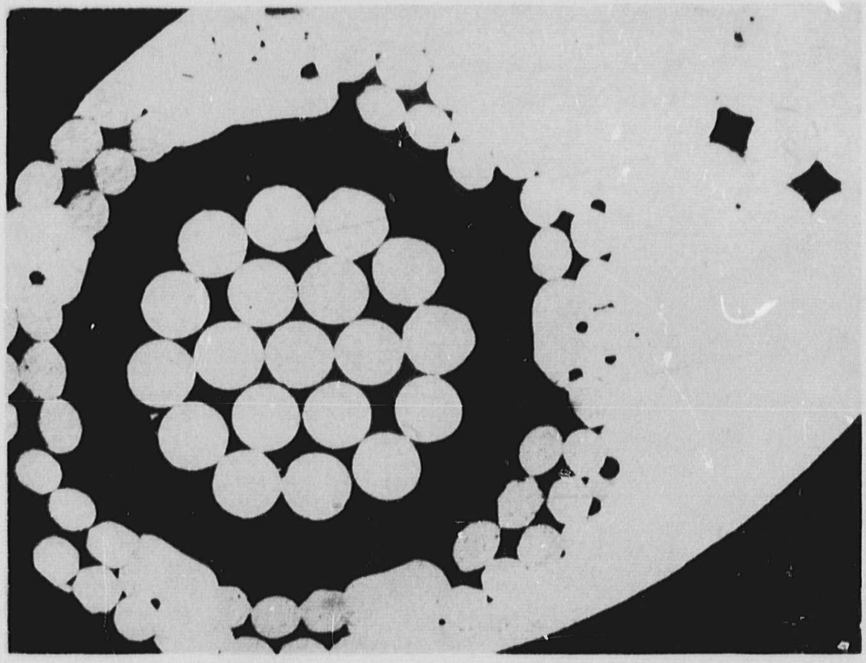


Figure 8. Immersion Test No. 1 Cross Section

2. Immersion Test No. 2.

a. Purpose. This test was performed using specimens of the configuration shown in figure 3b to determine if the solder sleeves would form a better water seal when two conductors were protruding from the solder sleeve instead of only one as in the case of the specimens of the previous test.

b. Test specimens. Twenty-five test specimens were fabricated for this test in the configuration shown in figure 3b. Conductor cables and pigtails were cut into 10.16 cm (4.0 inch) and 15.24 cm (6.0 inch) lengths,respectively.

c. Test procedure. A visual inspection was made of each specimen prior to testing. The immersion test was performed by suspending the specimens in a 5 percent salt solution (figure 6). The pigtails were turned up and inserted in holes provided in the support,and an insulation resistance measurement was made between the pigtail and salt solution immediately after immersion. After 24 hours of immersion, the insulation resistance measurements were repeated.

d. Test results. The results of the visual inspection are given in table 3. No wicking or voids were observed on these specimens. The test results are given in table 4. The results show that an additional lead coming from the solder sleeve did not improve the sealing effect of the solder sleeve.

There appears to be little, if any, correlation between the visual inspection results and test results. Comparison of results in tables 2 and 4 indicate that the sealing of the sleeve was less effective when two conductors protruded from the sleeve than when only one conductor protruded from the sleeve. Inspection of the specimens revealed that the sealing rings, when melted, failed to completely fill the void between the two conductors. In the case of only one conductor protruding from the sleeve the sealing ring flowed completely around the conductor.

3. Vibration Test.

a. Purpose. This test was performed to evaluate the performance of solder sleeve terminations when subjected to vibration tests as given in MIL-STD-202C, Method 204A, Test Condition B.

b. Test specimens. Twenty-five test specimens were prepared for this test. These specimens were made in the configuration of figure 3b, with a 45.72 cm (18 inch) pigtail to facilitate mounting on the vibration table.

c. Test procedure. A visual inspection was made of each specimen prior to testing. A voltage drop test was made on each specimen as described in paragraph B.1.c. of this section. This test was

performed in accordance with MIL-STD-202C, Method 204A, Test Condition B and was monitored by a continuity monitoring system. During the test, the specimens were connected in series and instrumented to indicate any failure of the connections or loss of continuity between the shield and the pigtail. The voltage drop test was repeated after the specimens were returned from the vibration test. A peel strength test was performed in which a peel pull was made on the solder connections.

d. Test results. The results of the visual inspection are given in table 5. No voids were observed, and wicking was observed on only five specimens. The test results are given in table 6. No significant changes in voltage drop were indicated as a result of the vibration test, and no failure (loss of electrical continuity) of the solder joints occurred during the vibration test.

The strength of the specimen ranged from 16.33 kg (36 pounds) to 18.24 kg (40.2 pounds). In each case the pigtail lead broke. Since a shear pull test was performed on these specimens, they exhibited a greater strength than those of immersion test number 1 on which a peel test was performed, see section II, paragraph B.

4. High Temperature Test.

a. Purpose. This test was performed to determine the effects of a sustained high temperature environment on solder sleeve connections.

b. Test specimen. Twenty-five specimens were fabricated for this test. The specimens were made in the configuration shown in figure 3b. Conductor cables were cut 10.16 cm (4.0 inches) in length and pigtails were 8.89 cm (3.5 inches) in length.

c. Test procedure. A visual inspection was made on each specimen prior to testing. A voltage drop test was performed on the specimen before and after conditioning. The specimens were conditioned at 125°C for 96 hours. Following environmental conditioning, four of the specimens were cross sectioned as metallurgical specimens. The remaining specimens were tested for shear strength.

d. Test results. The results of the visual inspection are given in table 7. No voids or wicking were observed. On one specimen a braid strand protruded through the sleeve and on two others

the pigtail slipped over conductor insulation during fabrication. Test results are given in table 8. No effects caused by temperature baking are indicated by the results. Peel strength ranged from 15.2 kg (33.5 pounds) to 18.37 kg (40.5 pounds) which was the breaking strength of each wire. Figure 9 shows photographs of the metallurgical sections. Transverse cross sections of specimens 10 and 18 (figure 9a and b) show that solder flow was not complete around the circumference of the braid. The longitudinal cross section of specimen 17 (figure 9c) shows that solder flowed into the braid at different places along the connections, leaving voids in about 50 percent of the braid. View d of figure 9, a blown up section of view b, indicates poor wetting action.

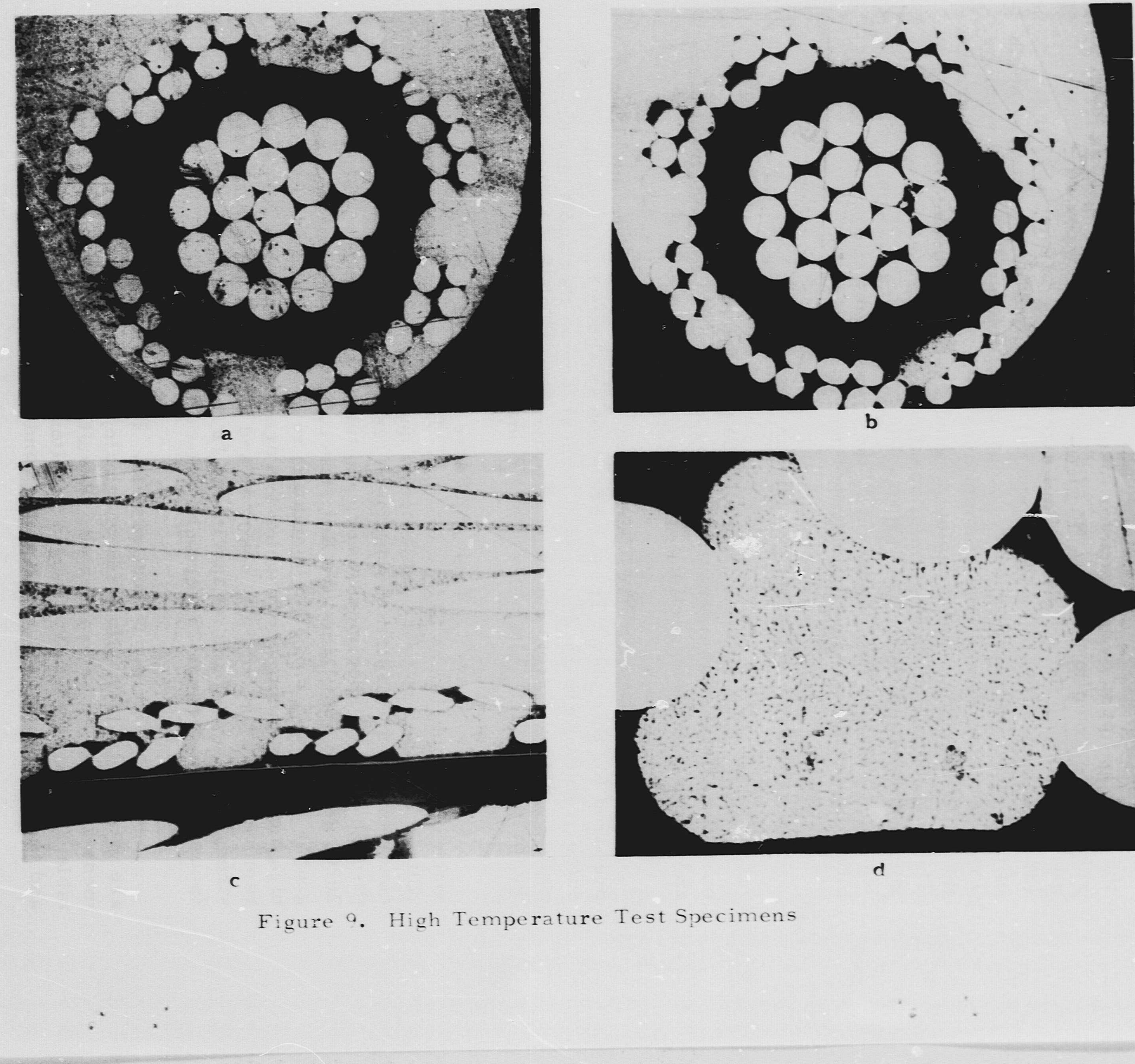
5. Moisture Resistance Test.

a. Purpose. The purpose of this test was to determine the effects of temperature cycling and high humidity on insulation and solder sleeve connections.

b. Test specimen. Twenty-five specimens were prepared for this test. These were made as shown in figure 3a. Conductor cables were 15.24 cm (6.0 inches) long so that sufficient braid could be removed from each end to prevent arcing from shield to conductor during high voltage tests of the insulation.

c. Test procedure. A visual examination was made of the specimens before testing. The specimens were tested for voltage drop before being subjected to humidity conditioning. Prior to conditioning, an insulation resistance test was made on specimens 1 through 11. All specimens were conditioned according to MIL-STD-202C, Method 106B Moisture Resistance, with the exception of paragraphs 2.4.2 and 2.5. The insulation resistance test was repeated at high humidity during conditioning and again after the specimens were removed from the humidity chamber and allowed to dry. A dielectric strength test was made on specimens 12 through 21 after conditioning. Specimens 22 through 25 were cross sectioned.

d. Test results. Results of the visual inspection are given in table 9. No voids or wicking were observed. Two specimens appeared to be overheated. Results of these tests are given in table 10. No significant changes resulted in voltage drop between initial and final readings as a result of the conditioning.



a b c d

Figure 9. High Temperature Test Specimens

Dielectric strength ranged from 2 kv to 9.2 kv, which is within the requirements of the wire (1.5 kv per MIL-W-16878). Figure 10 shows transverse and longitudinal cross sections of two specimens. These views show a good solder fillet between the pigtail and shield. Note that voids in cross section indicate poor wetting action on the braid, especially on the opposite side of the conductor from the pigtail.

C. SHEAR AND PEEL STRENGTH TESTS

Shear and peel strength tests were performed to determine the effect of removing the sleeve from the solder connection after fabrication. This includes both peel and shear type tests. The following configurations were tested.

(1) Shear Pull Test With Sleeve

(2) Shear Pull Test Without Sleeve

(3) Peel Pull Test With Sleeve

(4) Peel Pull Test Without Sleeve

1. Shear Pull Test With Sleeve.

a. Purpose. This test was performed to determine the shear pull strength of solder sleeve connections.

b. Test specimen. Twenty-five specimens were made in the configuration shown in figure 3b for this test. Conductor cables were cut 10.16 cm (4.0 inches) in length and pigtails were cut 8.89 cm (3.5 inches) in length.

c. Test procedure. A visual inspection was made of test specimens prior to testing. A voltage drop test was performed on the specimens to determine electrical consistency of the solder connections. This was followed by a shear type strength test.

d. Test results. Results of the visual inspection are given in table 11. On one specimen, a shield strand protruded into the sleeve. A void was observed in the solder joint of two specimens. The pull strength of these were among the lowest of the group (table 12). The shear strength of the specimens ranged from 14.95 kg (33 pounds)

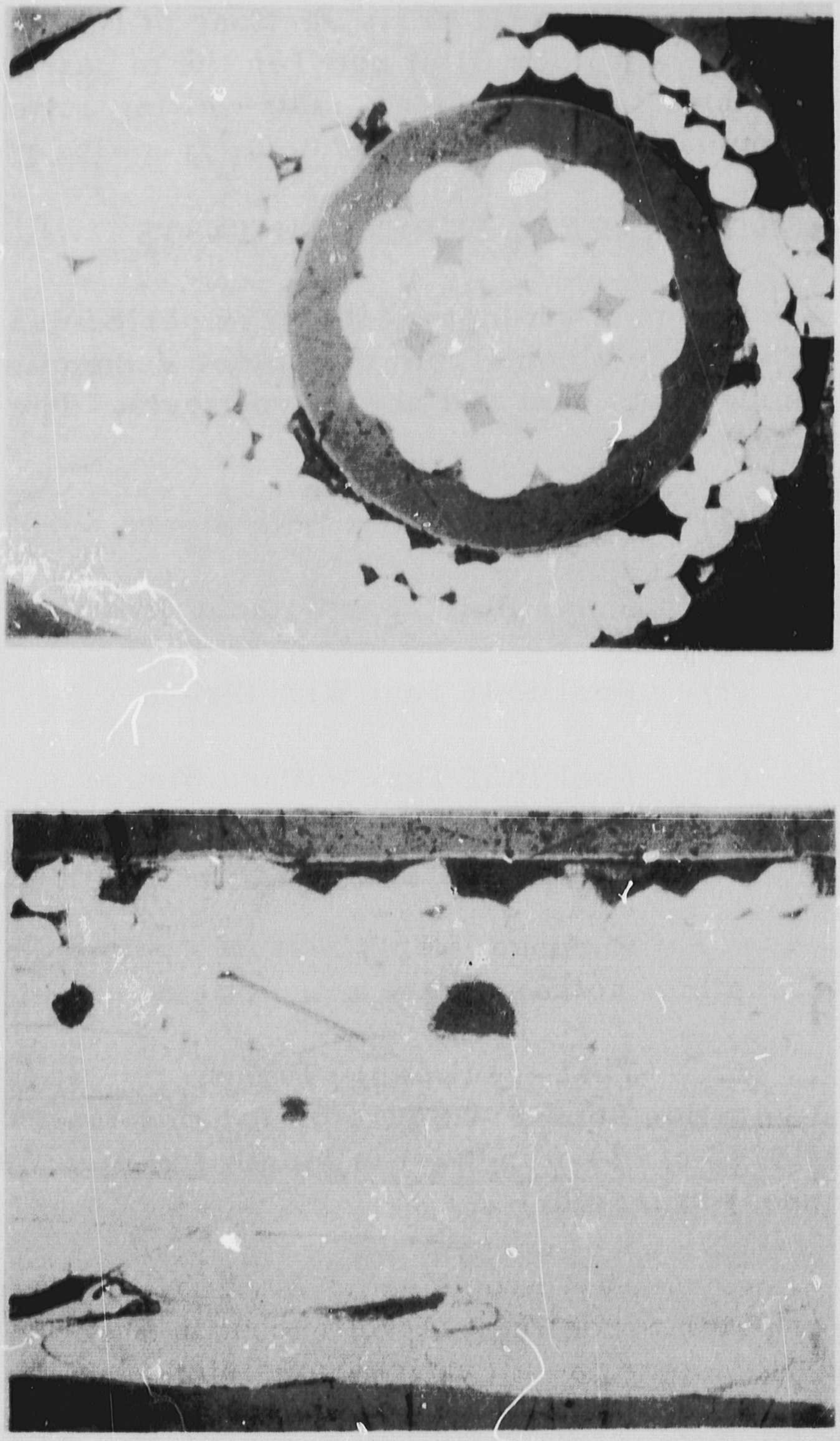


Figure 10. Moisture Resistance Test

to 18.6 kg (41 pounds). The average strength was 17.5 kg (38.6 pounds). In each case the pigtail lead broke during the shear strength test which indicates that the connection was stronger than the pigtail. The voltage drop ranged from 2.42 mv to 2.67 mv which is well within the requirement of 6.0 mv for ferrule joints per MIL-F-21608A.

2. Shear Pull Test Without Sleeve.

a. Purpose. The purpose of this test was to determine the shear pull strength of solder sleeve connections with the sleeve removed.

b. Test specimen. Twenty-five test specimens, identical to those described in paragraph C.1.b., were prepared for this test.

c. Test procedure. A visual inspection was made of test specimens prior to testing. A voltage drop test was performed on each specimen. The sleeve was removed from each specimen prior to the shear strength test.

d. Test results. The results of the visual inspection are given in table 13. A shield strand protruded through the sleeve on one specimen. Voltage drop and shear strength test results are given in table 14. Shear strength of the specimens ranged from 7.03 kg (15.5 pounds) to 17.2 kg (38 pounds). The average strength of the connections was 13.97 kg (30.8 pounds). Since the solder connection broke instead of the pigtail on most of these specimens, this test gives a better indication of the actual strength of the solder connection than the previous test.

3. Peel Pull Test With Sleeve.

a. Purpose. The purpose of this test was to determine peel strength of solder sleeve shield termination connections.

b. Test specimen. Twenty-five specimens were prepared for this test. These were made as shown in figure 3a. Conductor cables were cut 10.16 cm (4.0 inches) in length and pigtails were cut 8.89 cm (3.5 inches) in length.

c. Test procedure. A visual inspection was made of each specimen. Voltage drop and peel strength tests were performed. During this peel strength test the solder connection was subjected to a peel type pull.

d. Test results. Results of the visual inspection are given in table 15. A void was observed in the solder connection of one specimen. Results of this test are given in table 16. The peel strength ranged from 8.52 kg (18.8 pounds) to 10.5 kg (32.2 pounds). The average strength was 9.62 kg (21.2 pounds).

4. Peel Pull Test Without Sleeve.

a. Purpose. The purpose of this test was to determine the peel pull strength of the solder connection with the sleeve removed.

b. Test specimen. Twenty-five specimens were prepared for this test as shown in figure 3a. Conductor cables were 10.16 cm (4.0 inches) long and pigtails were 8.89 cm (3.5 inches) long.

c. Test procedure. A visual inspection of each specimen was made prior to testing. A voltage drop test was made on each specimen. The sleeve was removed before the specimen was given the peel strength test. Four specimens were cross sectioned.

d. Test results. Results of the visual inspection are given in table 17. On one specimen a shield strand and the pigtail protruded into the sleeve. The others appeared to be properly heated. The results of the voltage drop and peel strength tests are given in table 18. The peel strength of the specimens ranged from .907 kg (2 pounds) to 4.9 kg (10.8 pounds). The average peel strength was 1.86 kg (6.1 pounds). Note that the average peel strength, 1.86 kg (6.1 pounds), of the specimens peel pull tested without sleeves is well below the average peel strength, 9.2 kg (21.2 pounds), of those peel pull tested with sleeves in place. This indicates that the strength of the connections tested is largely due to the strength of the sleeve material and not to the solder. Figure 11 is a typical view of the specimens cross sectioned and indicates poor wetting of the shield.

D. FLUX RESIDUE, CORROSION TEST

1. Purpose. The purpose of this test was to determine if the flux residue in the solder connection contained any corrosive material.

2. Test Specimen. Twenty-five specimens were prepared for this test. These were made as shown in figure 3b with 10.16 cm (4 inch) conductor cables and 8.89 cm (3.5 inch) leads.

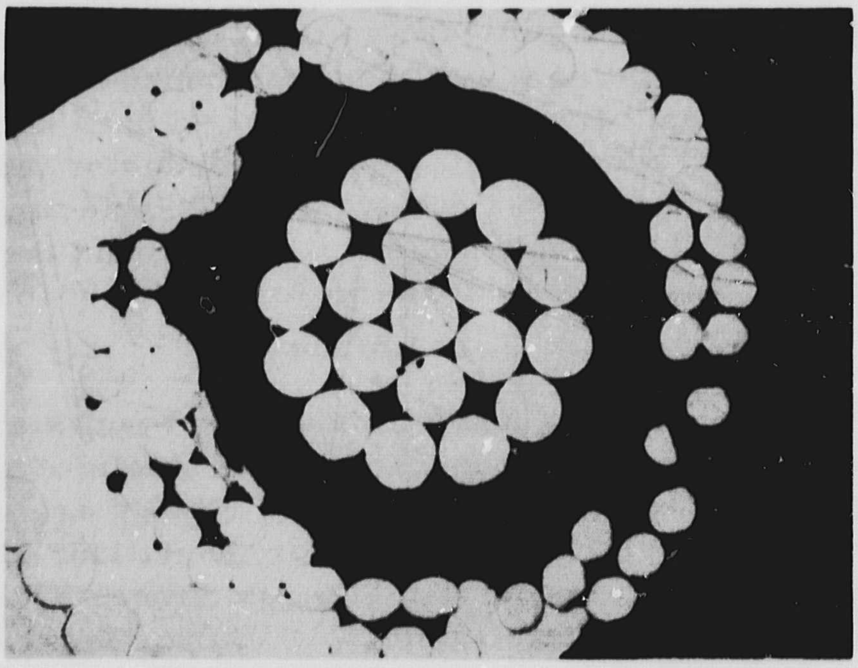


Figure 11. Peel Pull Test Without Sleeve

3. Test Procedure. A visual inspection was made of each specimen prior to testing. A voltage drop test was made on each specimen to determine electrical consistency of the joints. A sample number of specimens were randomly selected from the group for the corrosive residue test in which the sleeving on the solder connection was cut away and the exposed joint was examined microscopically. A resin like material was seen on each sample and a chloride determination test was performed using silver nitrate to determine the nature of the residue.

4. Test Results. Results of the visual inspection are given in table 19. One specimen exhibited a narrow fillet and two others had braid strands out of place. Table 20 gives results of the voltage drop test. No free chloride ions were detected in the chloride determination test which indicates that the residue in the solder sleeve was noncorrosive.

E. DIELECTRIC STRENGTH

1. Purpose. The purpose of this test was to determine the dielectric strength of the insulation between the solder connection and the conductor, and the dielectric strength of the solder sleeve.

2. Test Specimens. Five test specimens were prepared for this test. These were made as shown in figure 3a using 15.24 cm (6.0 inch) sections of conductor cable and 8.89 cm (3.5 inch) pigtail.

3. Test Procedure. Each specimen was visually inspected. A voltage drop test and dielectric strength test were performed on each specimen. The dielectric strength test was performed by use of Hypot. Electrodes were connected to the pigtail and the conductor, and the voltage was increased at approximately 500 volts per second until breakdown occurred. This gave the breakdown voltage of the conductor insulation. The dielectric strength of the sleeve was determined by connecting electrodes to the pigtail and a strip of foil which was wrapped around the sleeve over the solder connection. Voltage was again increased at approximately 500 volts per second until breakdown.

4. Test Results. Visual inspection results are given in table 21. Poor wetting action was observed on the shield of specimen number 5. Voltage drop and dielectric strength test results are given in table 22. On the dielectric strength test of conductor insulation, all specimens passed breakdown voltage requirements. The specimens arced at end of sleeve or outside of the sleeve area (table 22). During the dielectric strength test of the sleeves on one specimen, current arced from the foil through the end of the sleeve. The other specimens arced at points outside of the sleeve area.

F. VOLTAGE DROP AND PULL STRENGTH TESTS*

A group of solder sleeve shield termination specimens and stub splices, furnished by Manufacturing Engineering Laboratory, were tested in this program.

1. Purpose. These specimens were tested to determine electrical integrity and pull strength of the solder joint.

2. Specimens. The shield terminations were supplied as shown in figure 3b. Stub splices were made by crimping a ferrule sleeve over the connection and then covering with a Thermofit solder sleeve. Specimens tested were made using wire types given in table 23.

3. Test Procedure. Voltage drop and pull strength tests were performed on each specimen. Two specimens were cross sectioned.

4. Test Results. Results of these tests are given in table 24. The voltage drops ranged from 1.9 mv to 4.4 mv which is within limits (6 mv) of MIL-F-21608A for crimp ferrule shield terminations.

With the exception of specimen number 38 which broke at 7.25 kg (16 pounds), the pull strength of all specimens in this group exceeded

*Specimens furnished by Manufacturing Engineering Laboratory.

requirements of MIL-F-21608A, 15 pounds for size 22 wire and 19 pounds for size 20 wire. These ranged from 14.51 kg (32 pounds) to 18.87 kg (41.6 pounds). On 54 of the 63 specimens pull tested in this group the strength of the solder sleeve joint exceeded the strength of the pigtail. The metallurgical cross sections (figure 12) show solder flow into the braid; however, the number of voids present indicate poor wetting of the braid.

G. FABRICATION PROCESS

The preceding sections of this report covered tests of specimens made from nickel plated wire which were fabricated in the normal manner. Metallurgical sections of the specimens tested indicated that better wetting of the shield is desirable. The following tests were conducted in an attempt to discover a process which would produce better wetting on nickel plated wire.

(1) Solder Sleeve Connections Using Prefluxed Shield

(2) Heat Time Versus Peel Strength Test

1. Solder Sleeve Connections Using Prefluxed Shield.

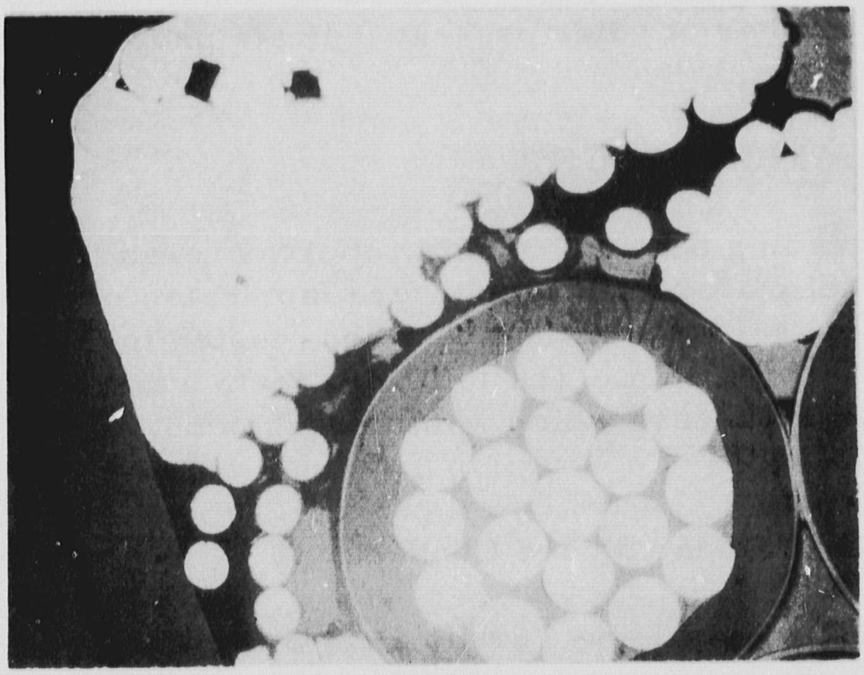
a. Purpose. The purpose of this test was to determine the effects on the solder joint by fluxing the shield braid prior to fabrication of the connection.

b. Test specimens. Twenty-seven test specimens were prepared for this test. These were made as shown in figure 3a. Prior to assembly, one drop of Kester 1544 flux was applied to the shield braid.

c. Test procedure. The test specimens were visually inspected. Voltage drop and peel strength tests were made on the specimens. Prior to the peel strength test the sleeve was cut away from the solder connection. Two of the specimens were molded for metallurgical specimens and two specimens were tested for corrosive residue.

d. Test results. Results of the visual inspection are shown in table 25. One specimen leaked solder from the sleeve and another one had a shield strand protruding through the sleeve.

Results of the voltage drop and peel strength tests are given in table 26. The peel strength ranged from 2.94 kg (6.5 pounds) to 6.35 kg (14 pounds). The average strength was 4.67 kg (10.3 pounds). The cross sections (figure 13) show that the addition of flux resulted in increased wetting of the shield braid. Note an almost complete absence of voids in



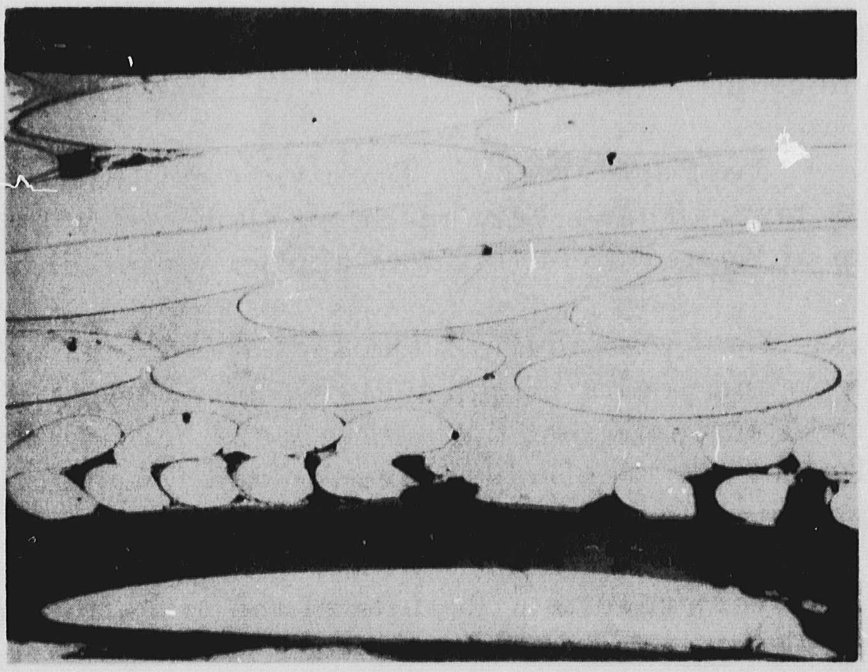
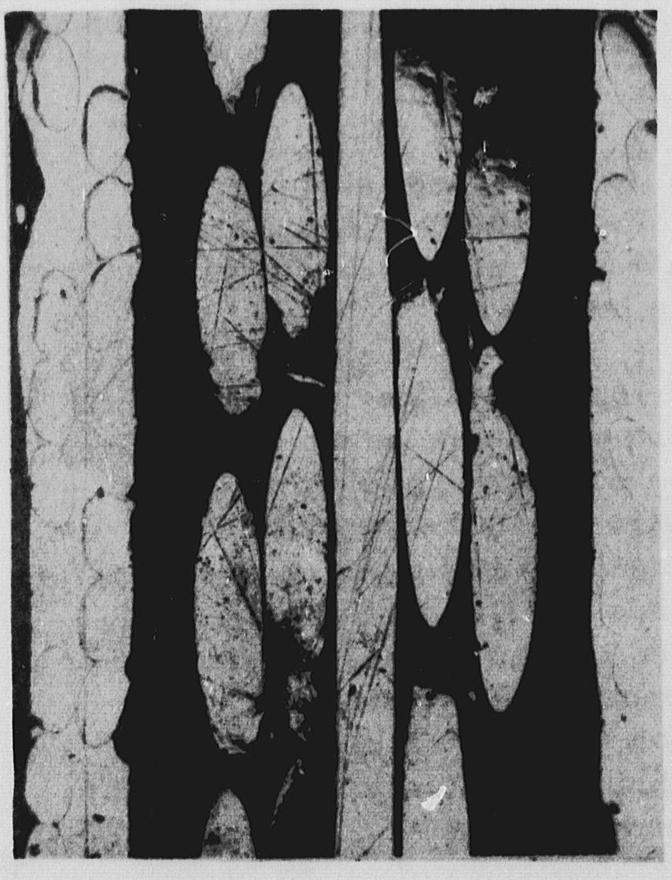
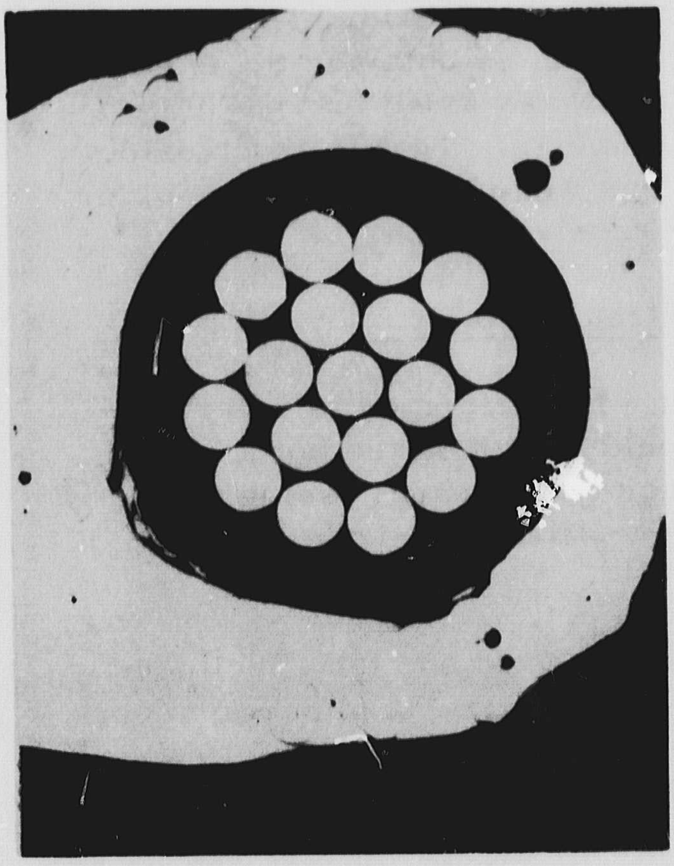


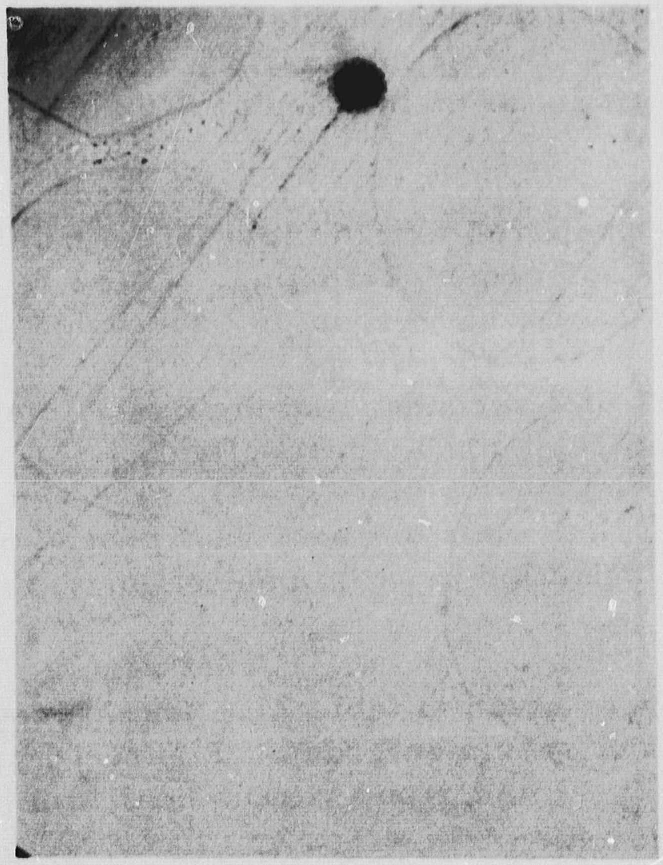
Figure 12. Manufacturing Engineering Laboratory Test Specimens



a. Longitudinal Section of **Specimen 24**



b. **Transverse Section of** Specimen 25



c. **Enlarged** Section of The **Shield and Solder** in View b

Figure 13. Heat Time Versus Peel Strength Test

the solder and complete solder flow is observed in the braid. This test shows that desirable wetting of the nickel braid can be obtained by use of an active flux. However, after further testing it was found that the flux residue in the solder sleeve was corrosive in nature. That is, a chloride ion determination test showed that chloride ions were present in the solder sleeve, the presence of which could cause corrosive action.

2. Heat Time Versus Peel Strength Test.

a. Purpose. This test was performed to determine the amount of time that the solder sleeve should be left in the hot air stream of the gun during fabrication to produce the strongest solder connection. During fabrication of the solder connection, the air in the heat reflector was maintained at 315 (± 3)°C.

b. Test specimen. One hundred and ten specimens were prepared for this test in the configuration of figure 3a plus two specimens for cross sectioning. These were divided into 11 groups of 10 specimens each and 1 group of 2 specimens. Each group of 10 specimens was heated for a specific period of time ranging from 12 to 32 seconds in increments of 2 seconds, and the 2 specimens of the last group were heated for 18 and 24 seconds, respectively.

c. Test procedure. The sleeve was cut away from the connection prior to peel strength testing.

d. Test results. Results of the peel strength tests are given in table 27. The average peel strength was calculated for each specimen group. Figure 14 gives average peel strength of each specimen group versus heat time during fabrication.

Note that during heat periods of 12 to 16 seconds the peel strength increased from 1.85 kg (4 pounds) to about 3.4 kg (7.5 pounds). During this time the solder ring collapsed around the connection, forming a mechanical connection only which was relatively strong at a 16 second heat period. As the heat time increased from 16 to 18 seconds, wetting action of the solder was poor and the solder tended to recede from around the braid or remained in spots, thereby resulting in connections of decreased strength. As the heat time was increased from 18 seconds to 30 seconds, except for a small decrease at 26 seconds, the plateau on the curve from 22 seconds to 26 seconds indicates the heat periods at which consistently strong solder sleeve connections can be made on the type of wire used.

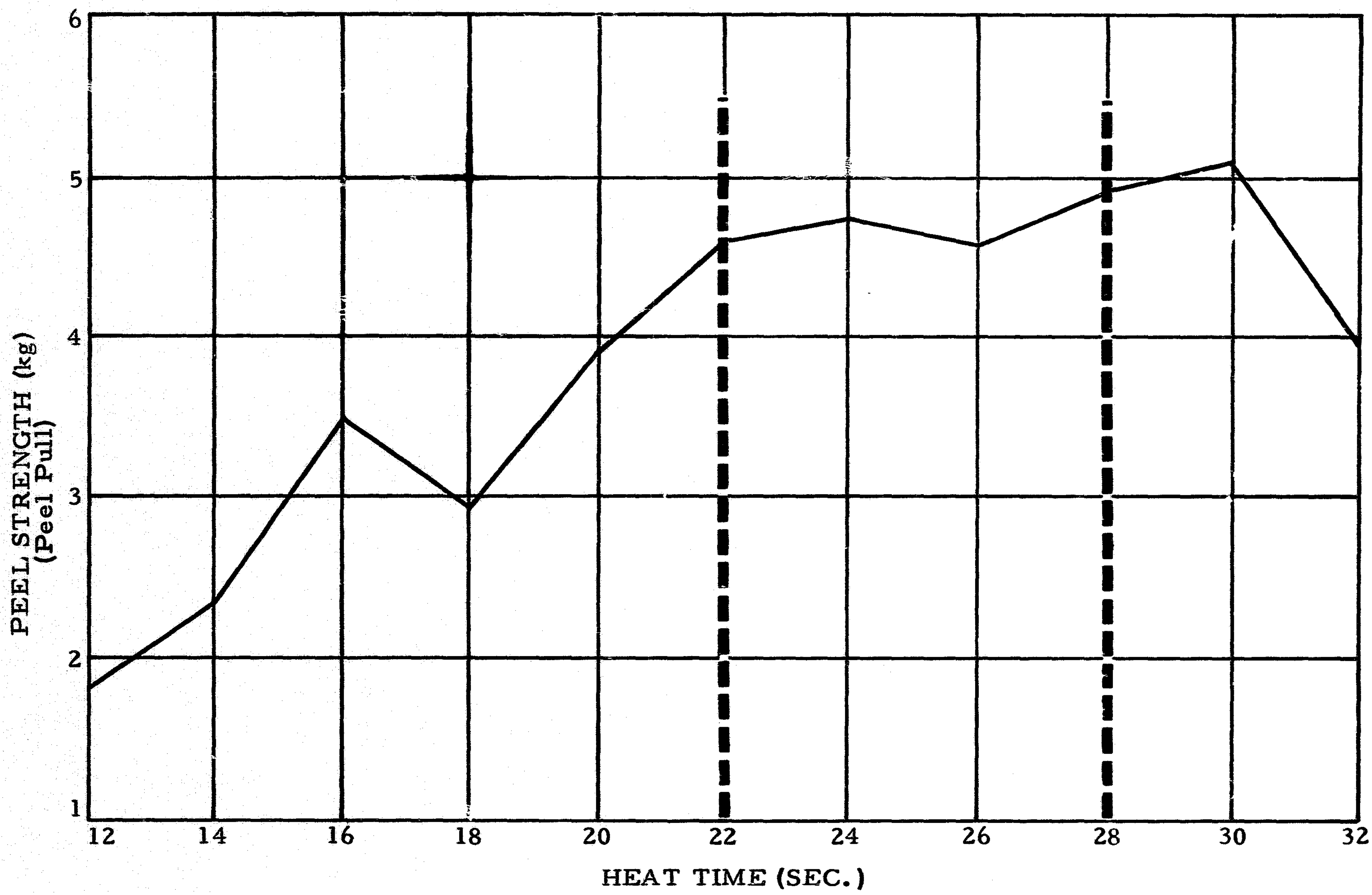


Figure 14. Peel Strength Resulting from Various Heat Periods at 315°C

Figure 15 shows cross-section views of two specimens which were fabricated at different heat periods. View "a" shows a specimen on which heat was applied for 18 seconds. Note that solder flow was not complete around the shield and a large area of the braid contains no solder. The specimen shown at view "b" was heated for 24 seconds. Note that solder flowed completely around the shield and the smaller amount of voids indicate better wetting action on this specimen. Comparing the heat time of these specimens to the graph in figure 14, it can be seen that 18 seconds is the area where strength fell off and 24-second heat period produced highest peel strength connections.

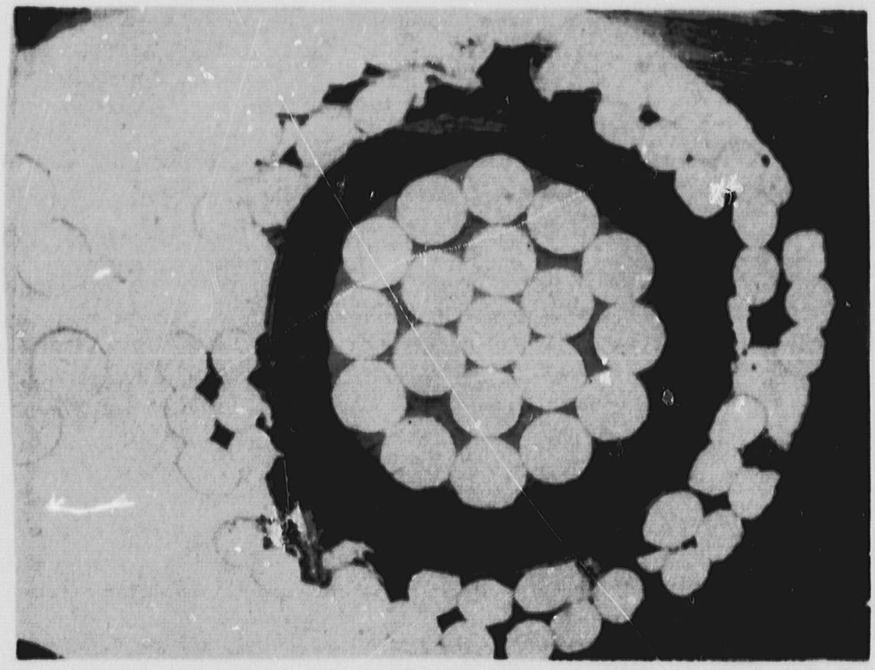
SECTION IV. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

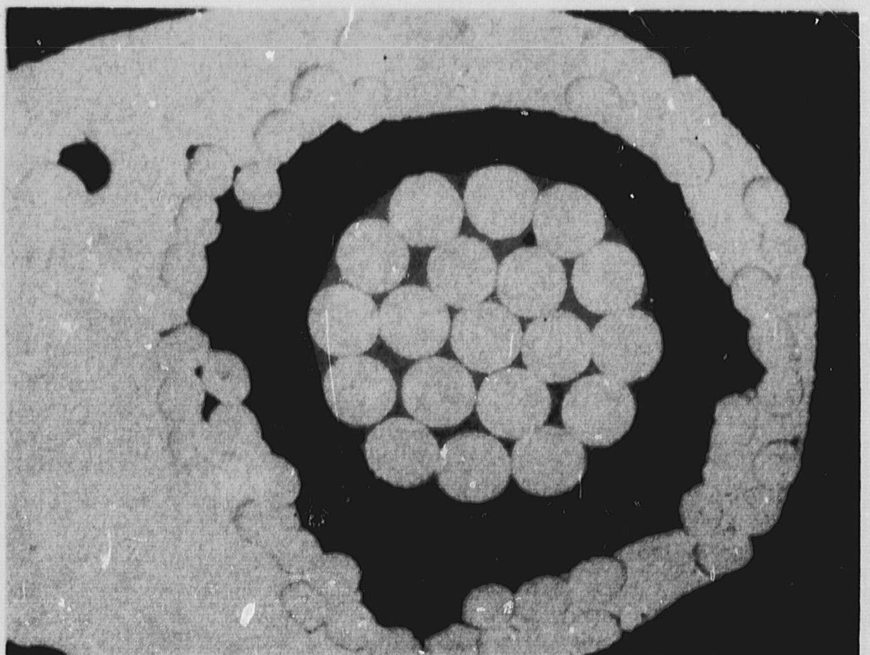
It is concluded from this series of tests that Thermofit solder sleeve shield terminations, when fabricated by a properly controlled process, meet the requirements of MIL-F-21608A for crimp style shield termination when used with nickel clad copper and alloy 63 wire. A properly controlled fabrication process is one that has been proven to produce acceptable joints by testing. This testing would include determination of best temperature at which the sleeves are heated and the best heating period. In-process tests should be made periodically to insure that these parameters are maintained.

B. RECOMMENDATIONS

Prior to initiation of a program using solder sleeves for wire connections it is recommended that a test similiar to that described in section III, paragraph G.2 be carried out to determine optimum heat time and also temperature of the hot airflow for best solder results on the materials used. These parameters will vary with type wire, wire size, and number of conductors in the cables.



a. Cross Section of Specimen Using 18 Second Heat Time



b. Cross Section of Specimen Using 24 Second Heat Time

Figure 15. Metallurgical Specimens for Heat Time Versus Peel Strength Test

APPENDIX A
REFERENCE MATERIAL LIST

1. MIL-F-21608A

2. MIL-STD-202C

3. AD 459811, Defense Documentation Center
   Defense Supply Agency
   Cameron Station, Alexandria, Virginia

4. MIL-W-16878

5. Vibration Testing of Thermofit Solder Sleeves
   Rayclad Tubes Incorporated, Laboratory Report No. 679

6. Corrosion Testing of Nickel Wetting Fluxes Used in Thermofit Solder Sleeves
   Rayclad Tubes Incorporated, Laboratory Report No. 742

7. Qualification Testing of Thermofit Solder Sleeve D-101-20
   Rayclad Tubes Incorporated, Laboratory Report No. 752

8. Qualification Testing of Thermofit Solder Sleeve D-101-00
   Rayclad Tubes Incorporated, Laboratory Report No. 753

9. Qualification Testing of Thermofit Solder Sleeve D-121-00
   Rayclad Tubes Incorporated, Laboratory Report No. 754

10. Performance Testing of Thermofit Solder Sleeves D-100-WE
    Rayclad Tubes Incorporated, Laboratory Report No. 710

11. Corrosion Testing of Rayclad Tubes Solder Sleeves
    Rayclad Tubes Incorporated, Laboratory Report No. 662

12. Performance Testing of Rayclad Tubes Solder Sleeves D-101
    Rayclad Tubes Incorporated, Laboratory Report No. 661

13. Copper Mirror Corrosion Test of Rayclad Solder Sleeves
    Rayclad Tubes Incorporated, Laboratory Report No. 686

REFERENCE MATERIAL LIST (Continued)

14. Reliability of Solder Joints made with Thermofit Solder Sleeves on Shielding which has been subjected to Prolonged Atmospheric exposure
Rayclad Tubes Incorporated, Laboratory Report No. 690

15. The Effect of Heat on Primary Insulation During Installation of Rayclad Solder Sleeves
Rayclad Tubes Incorporated, Laboratory Report No. 671

16. The Effect of Temperature on the Tensile Strength of Shield Terminations made with Thermofit Solder Sleeves D-101 and D-121
Rayclad Tubes Incorporated, Laboratory Report No. 737

17. Tensile Strength of Solder Joints at 300°F
Rayclad Tubes Incorporated, Laboratory Report No. 666

APPENDIX B
TEST DATA

Samples with incomplete test data were removed for metallurgical specimens.

Table 1. Immersion Test No. 1 Visual Inspection

Specimen No.	Heat	Remarks
1	P	Darkened sleeve
2	P	No defects observed
3	P	No defects observed
4	P	No defects observed
5	P	No defects observed
6	O	Pigtail poor wetting
7	P	No defects observed
8	P	Incomplete wetting at fillet
9	P	No defects observed
10	P	No defects observed
11	O	Insufficient solder at joint
12	O	Insufficient solder at joint
13	O	Insufficient solder at joint
14	O	Insufficient solder at joint
15	P	No defects observed
16	P	No defects observed
17	P	No defects observed
18	P	No defects observed
19	P	No defects observed
20	P	No defects observed
21	P	No defects observed
22	P	No defects observed
23	P	No defects observed
24	P	No defects observed
25	P	No defects observed

O = Overheated
P = Properly Heated

Table 2. Immersion Test No. 1 Test Results

Specimen No.	Voltage Drop (mv)		Insulation Resistance in Salt Water (megohms)		Strength (Peel)		Remarks
	Initial	Final	Initial	After 24 Hr	(kg)	(lb)	
1	2.46	2.40	3×10^4	Short	8.85	19.5	Peeled
2	2.34	2.26	Short	Short	8.61	19.0	Peeled
3	2.34	2.40	8×10^5	Short	6.35	14.0	Peeled
4	2.4	2.34	Short	Short			
5	2.42	2.52	9×10^5	Short	8.39	18.5	Pulled braid apart
6	2.5	2.5	Short	Short	8.85	19.5	Peeled
7	2.3	2.27	6×10^5	Short	9.52	21.0	Peeled
8	2.35	2.31	9×10^5	Short	10.2	22.5	Peeled
9	2.36	2.36	Short	Short	6.57	14.5	Peeled
10	2.46	2.41	9×10^5	Short	7.03	15.5	Peeled
11	2.5	2.4	Short	Short	8.39	18.5	Peeled
12	2.47	2.44	1 meg	Short	9.29	20.5	Peeled
13	2.[illegible]	2.34	Short	Short			
14	2.39	2.41	Short	Short	5.44	12.0	Peeled
15	2.33	2.33	Short	Short	8.61	19.0	Peeled
16	2.43	2.33	9×10^5	2×10^5			
17	2.46	2.46	10×10^5	2×10^5	7.25	16.0	Peeled
18	2.49	2.35	11×10^5	8×10^5	8.16	18.0	Peeled
19	2.53	2.46	11×10^5	Short	9.07	20.0	Peeled
20	2.5	2.31	Short	Short	8.85	19.5	Peeled
21	2.37	2.45	Short	Short	8.16	18.0	Peeled
22	2.39	2.31	10×10^5	Short	5.66	12.5	Peeled
23	2.79	2.76	10×10^5	Short			
24	2.37	2.40	Short	Short	7.21	15.9	Peeled
25	2.31	2.23	Short	Short	7.93	17.5	Peeled

Table 3. Immersion Test No. 2 Visual Inspection

Specimen No.	Heat	Remarks
1	P	No defects observed
2	P	Solder did not cover area well
3	P	No defects observed
4	P	No defects observed
5	P	No defects observed
6	P	No defects observed
7	P	No defects observed
8	P	No defects observed
9	P	No defects observed
10	P	Void in fillet
11	P	Poor wetting on braid
12	P	
13	P	Overlapping of joint
14	P	Braid strand protruding sleeve
15	P	
16	O	Insufficient solder at joint
17	P	
18	P	Poor wetting on shield
19	P	No defects observed
20	P	No defects observed
21	P	No defects observed
22	P	No defects observed
23	P	Braid protruding shield
24	P	No defects observed
25	P	No defects observed

O = Overheated

P = Properly Heated

Table 4. Immersion Test No. 2 Test Results

Specimen No.	Insulation Resistance in Salt Water Solution (Megohms)	
	Initial	After 24 Hr
1	10×10^5	Short
2	Short	Short
3	10×10^5	Short
4	1×10^5	Short
5	3×10^5	Short
6	2×10^5	Short
7	4×10^5	10×10^5
8	2×10^5	2×10^5
9	1.5×10^5	Short
10	Short	Short
11	2×10^5	Short
12	8×10^5	Short
13	3.5×10^5	Short
14	4×10^5	Short
15	8×10^4	5×10^4
16	4×10^5	Short
17	10×10^5	Short
18	1×10^5	Short
19	Short	Short
20	Short	Short
21	Short	Short
22	Short	Short
23	Short	1×10^5
24	Short	1×10^5
25	Short	Short

Table 5. Vibration Test Visual Inspection

Specimen No.	Heat	Remarks
1	P	No defects noted
2	P	No defects noted
3	P	No defects noted
4	O	Insufficient solder in joint
5	P	Slight wicking
6	P	Insufficient solder in joint
7	O	Slight wicking
8	P	No defects noted
9	P	Slight wicking
10	P	Slight wicking
11	P	No defects noted
12	P	No defects noted
13	P	No defects noted
14	P	No defects noted
15	P	No defects noted
16	P	No defects noted
17	O	Insufficient solder in joint
18	P	No defects noted
19	P	No defects noted
20	P	No defects noted
21	P	No defects noted
22	P	No defects noted
23	O	Insufficient solder on pigtail
24	P	No defects noted
25	P	Pigtail under wetted

O = Overheated
P = Properly Heated

Table 6. Vibration Test Test Results

Specimen No.	Voltage Drop (mv)		Strength		Remarks
	Initial	Final	(kg)	(lb)	
1	2.41	2.41	17.69	39.0	Pigtail broke
2	2.5	2.32	17.69	39.0	Pigtail broke
3	2.41	2.26	17.24	38.0	Pigtail broke
4	2.34	2.22	16.78	37.0	Pigtail broke
5	2.41	2.32	17.69	39.0	Pigtail broke
6	2.47	2.32	17.24	38.0	Pigtail broke
7	2.4	2.30	16.33	36.0	Pigtail broke
8	2.5	2.31	17.00	37.5	Pigtail broke
9	2.41	2.32	16.78	37.0	Pigtail broke
10	2.42	2.25	17.24	38.0	Pigtail broke
11	2.48	2.27	17.69	39.0	Pigtail broke
12	2.5	2.29	18.05	39.8	Pigtail broke
13	2.44	2.35	17.69	39.0	Pigtail broke
14	2.43	2.35	16.78	37.0	Pigtail broke
15	2.51	2.45	16.69	36.8	Pigtail broke
16	2.47	2.42	16.87	37.2	Pigtail broke
17	2.44	2.36	18.14	40.0	Pigtail broke
18	2.53	2.47	17.00	37.5	Pigtail broke
19	2.40	2.27	17.78	39.2	Pigtail broke
20	2.52	2.40	18.23	40.2	Pigtail broke
21	2.52	2.41	16.78	37.0	Pigtail broke
22	2.41	2.33	16.78	37.0	Pigtail broke
23	2.42	2.33	16.33	36.0	Pigtail broke
24	2.48	2.39	17.32	38.2	Pigtail broke

Table 7. High Temperature Test Visual Inspection

Specimen No.	Heat	Remarks
1	P	No defects observed
2	P	No defects observed
3	P	No defects observed
4	P	No defects observed
5	P	No defects observed
6	P	No defects observed
7	P	No defects observed
8	P	No defects observed
9	P	No defects observed
10	P	No defects observed
11	P	Pigtail overlap shield insulation
12	P	No defects observed
13	P	No defects observed
14	P	No defects observed
15	P	No defects observed
16	P	No defects observed
17	P	Overlapping pigtail
18	P	No defects observed
19	P	No defects observed
20	P	No defects observed
21	P	No defects observed
22	P	Braid strands standing up
23	P	No defects observed
24	P	No defects observed
25	P	No defects observed

P = Properly Heated

Table 8. High Temperature Test Test Results

Specimen No.	Voltage Drop (mv) Initial	Voltage Drop (mv) After Baking	Shear Pull Strength (kg)	Shear Pull Strength (lb)	Remarks
1	2.55	2.52	17.69	39.0	Pigtail broke
2	2.53	2.42	18.37	40.5	Pigtail broke
3	2.70	2.46	17.92	39.5	Pigtail broke
4	2.46	2.4	17.92	39.5	Pigtail broke
5	2.45	2.6	18.14	40.0	Pigtail broke
6	2.56	2.6	17.92	39.5	Pigtail broke
7	2.55	2.61	18.37	40.5	Pigtail broke
8	2.44	2.41	18.05	39.8	Pigtail broke
9	2.41	2.46	17.69	39.0	Pigtail broke
10	2.3	2.38			
11	2.52	2.43	18.14	40.0	Pigtail broke
12	2.38	2.40	17.69	39.0	Pigtail broke
13	2.39	2.42	17.69	39.0	Pigtail broke
14	2.47	2.5	15.88	35.0	Pigtail broke
15	2.48	2.47	17.69	39.0	Pigtail broke
16	2.4	2.43	17.69	39.0	Pigtail broke
17	2.37	2.45			
18	2.52	2.54			
19	2.4	2.56	18.14	40.0	Pigtail broke
20	2.46	2.4	18.14	40.0	Pigtail broke
21	2.41	2.45	18.37	40.5	Pigtail broke
22	2.43	2.4			
23	2.48	2.47	15.20	33.5	Pigtail broke
24	2.46	2.51	17.92	39.5	Pigtail broke
25	2.41	2.52	17.46	38.5	Pigtail broke

Table 9. Moisture Resistance Test Specimens Visual Inspection

Specimen No.	Heat	Remarks
1	P	No defects observed
2	P	No defects observed
3	P	No defects observed
4	P	No defects observed
5	P	No defects observed
6	P	No defects observed
7	P	No defects observed
8	P	No defects observed
9	P	No defects observed
10	P	No defects observed
11	O	Insufficient solder in joint
12	P	No defects observed
13	P	No defects observed
14	P	No defects observed
15	P	No defects observed
16	P	No defects observed
17	P	No defects observed
18	P	No defects observed
19	P	No defects observed
20	P	No defects observed
21	O	Insufficient solder in joint
22	P	No defects observed
23	P	No defects observed
24	P	No defects observed
25	P	No defects observed

O = Overheated
P = Properly Heated

Table 10. Moisture Resistance Test

Specimen No.	Voltage Drop (mv)		Insulation Resistance (megohms)			Dielectric Strength (kv)	Location of High Voltage Breakdown
	Initial	Final	Before Conditioning	After Conditioning	After Drying		
1	2.48	2.5	14×10^5	*	*		
2	2.48	2.46	11×10^5	*	*		
3	2.56	2.43	12×10^5	*	*		
4	2.4	2.33	11×10^5	*	*		
5	2.38	2.22	11×10^5	*	*		
6	2.36	2.21	11×10^5	*	*		
7	2.39	2.33	11×10^5	*	*		
8	2.36	2.24	11×10^5	*	17×10^5		
9	2.36	2.25	11×10^5	*	*		
10	2.41	2.24	11×10^5	*	18×10^5		
11	2.55	2.28	11×10^5	*	18×10^5		
12	2.37	2.18				7	At end of shield
13	2.38	2.36				9.2	1/2 in. above sleeve
14	2.36	2.24				9	2 in. above sleeve
15	2.26	2.14				4.8	Under sleeve
16	2.34	2.24				9	1/2 in. above sleeve
17	2.37	2.26				2	In joint
18	2.37	2.23				6.6	In joint
19	2.25	2.2				7.5	Lower end of joint
20	2.39	2.3				5	Under sleeve
21	2.39	2.43				8.2	Under sleeve
22**	2.38	2.29					
23**	2.35	2.33					
24**	2.31	2.23					
25**	2.33	2.33					

*Greater than 20×10^5 megohm **Metallurgical specimen

Table 11. Shear Pull Test With Sleeve Visual Inspection

Specimen No.	Heat	Remarks
1	P	No defects observed
2	P	No defects observed
3	P	No defects observed
4	P	No defects observed
5	P	Shield strand protruding into sleeve
6	P	No defects observed
7	P	No defects observed
8	P	No defects observed
9	P	Void in fillet
10	P	No defects observed
11	P	No defects observed
12	P	No defects observed
13	P	No defects observed
14	P	No defects observed
15	P	No defects observed
16	P	No defects observed
17	P	No defects observed
18	P	No defects observed
19	P	No defects observed
20	P	No defects observed
21	P	No defects observed
22	P	No defects observed
23	P	No defects observed
24	P	No defects observed
25	P	Void in fillet

P = Properly Heated

Table 12. Shear Pull Test with Sleeve Test Results

Specimen No.	Voltage Drop (mv)	Strength		Remarks
		(kg)	(lb)	
1	2.56	18.14	40.0	Pigtail broke
2	2.67	18.23	40.2	Pigtail broke
3	2.59	18.51	40.8	Pigtail broke
4	2.54	17.46	38.5	Pigtail broke
5	2.61	16.69	39.0	Pigtail broke
6	2.51	18.05	39.8	Pigtail broke
7	2.52	18.23	40.2	Pigtail broke
8	2.61	18.55	40.9	Pigtail broke
9	2.55	14.96	33.0	Pigtail broke
10	2.56	16.69	39.0	Pigtail broke
11	2.57	18.51	40.8	Pigtail broke
12	2.56	17.00	37.5	Pigtail broke
13	2.42	15.88	35.0	Pigtail broke
14	2.52	18.14	40.0	Pigtail broke
15	2.47	17.33	38.2	Pigtail broke
16	2.48	17.78	39.2	Pigtail broke
17	2.48	18.60	41.0	Pigtail broke
18	2.57	16.78	37.0	Pigtail broke
19	2.5	18.14	40.0	Pigtail broke
20	2.47	18.19	40.1	Pigtail broke
21	2.59	16.33	36.0	Pigtail broke
22	2.54	17.24	38.0	Pigtail broke
23	2.58	17.24	38.0	Pigtail broke
24	2.62	17.78	39.2	Pigtail broke
25	2.56	16.33	36.0	Pigtail broke

Table 13. Shear Pull Test Without Sleeve Visual Inspection

Specimen No.	Heat	Remarks
1	P	No defects observed
2	P	No defects observed
3	P	No defects observed
4	P	No defects observed
5	P	No defects observed
6	P	No defects observed
7	P	No defects observed
8	P	No defects observed
9	P	No defects observed
10	P	No defects observed
11	P	No defects observed
12	P	No defects observed
13	P	No defects observed
14	P	Pigtail protruding through sleeve
15	P	No defects observed
16	P	No defects observed
17	P	No defects observed
18	P	No defects observed
19	P	No defects observed
20	P	No defects observed
21	P	No defects observed
22	P	No defects observed
23	P	No defects observed
24	P	No defects observed
25	P	No defects observed

P = Properly Heated

Table 14. Shear Pull Test Without Sleeve Test Results

Specimen No.	Voltage Drop (mv)	Strength (kg)	(lb)	Remarks
1	2.55	16.33	36.0	Pulled out braid
2	2.43	16.78	37.0	Pigtail broke
3	2.48	17.24	38.0	Braid broke
4	2.38	15.88	35.0	Pigtail broke
5	2.46	17.24	38.0	Braid broke
6	2.5	7.71	17.0	Braid broke
7	2.46	8.39	18.5	Braid broke
8	2.48	7.25	16.0	Braid broke
9	2.48	8.16	18.0	Braid broke
10	2.5	7.03	15.5	Braid broke
11	2.47	17.15	37.8	Braid broke
12	2.46	17.15	37.8	Braid broke
13	2.48	14.96	33.0	Braid broke
14	2.46	8.39	18.5	Braid broke
15	2.4	16.33	36.0	Braid broke
16	2.45	16.33	36.0	Braid broke
17	2.41	7.71	17.0	Braid broke
18	2.47	16.78	37.0	Braid broke
19	2.46	17.15	37.8	Pigtail broke
20	2.42	16.24	35.8	Braid broke
21	2.37	16.19	35.7	Braid broke
22	2.49	14.96	33.0	Braid broke
23	2.45	16.10	35.5	Pigtail broke
24	2.45	17.24	38.0	Braid broke
25	2.53	15.42	34.0	Braid broke

Table 15. Peel Pull Test With Sleeve Visual Inspection

Specimen No.	Heat	Remarks
1	P	Void in fillet
2	P	No defects observed
3	P	No defects observed
4	P	No defects observed
5	P	No defects observed
6	P	No defects observed
7	P	No defects observed
8	P	No defects observed
9	P	No defects observed
10	P	No defects observed
11	P	No defects observed
12	P	No defects observed
13	P	No defects observed
14	P	No defects observed
15	P	No defects observed
16	P	No defects observed
17	P	No defects observed
18	P	No defects observed
19	P	No defects observed
20	P	No defects observed
21	P	No defects observed
22	P	No defects observed
23	P	No defects observed
24	P	No defects observed
25	P	No defects observed

P = Properly Heated

Table 16. Peel Pull Test With Sleeve Test Results

Specimen No.	Voltage Drop (mv)	Strength (kg)	Strength (lb)	Remarks
1	2.47	9.53	21.0	Pigtail peeled
2	2.44	9.89	21.8	Pigtail peeled
3	2.44	10.30	22.7	Pigtail peeled
4	2.49	10.43	23.0	Pigtail peeled
5	2.43	9.53	21.0	Pigtail peeled
6	2.5	9.07	20.0	Pigtail peeled
7	2.51	8.62	19.0	Pigtail peeled
8	2.39	8.62	19.0	Pigtail peeled
9	2.42	10.53	23.2	Pigtail peeled
10	2.48	10.34	22.8	Pigtail peeled
11	2.41	9.53	21.0	Pigtail peeled
12	2.5	9.07	20.0	Pigtail peeled
13	2.36	9.98	22.0	Pigtail peeled
14	2.5	9.98	22.0	Pigtail peeled
15	2.44	9.43	20.8	Pigtail peeled
16	2.43	9.43	20.8	Pigtail peeled
17	2.49	9.07	20.0	Pigtail peeled
18	2.45	9.30	20.5	Pigtail peeled
19	2.48	10.07	22.2	Pigtail peeled
20	2.43	10.07	22.2	Pigtail peeled
21	2.53	10.25	22.6	Pigtail peeled
22	2.53	8.71	19.2	Pigtail peeled
23	2.59	10.16	22.4	Pigtail peeled
24	2.49	9.16	20.2	Pigtail peeled
25	2.43	8.53	18.8	Pigtail peeled

Table 17. Peel Pull Test Without Sleeve Visual Inspection

Specimen No.	Heat	Remarks
1	P	No defects observed
2	P	No defects observed
3	P	No defects observed
4	P	No defects observed
5	P	No defects observed
6	P	No defects observed
7	P	No defects observed
8	P	No defects observed
9	P	No defects observed
10	P	No defects observed
11	P	No defects observed
12	P	No defects observed
13	P	No defects observed
14	P	No defects observed
15	P	No defects observed
16	P	No defects observed
17	P	Shield strand & pigtail standing up into sleeve
18	P	No defects observed
19	P	No defects observed
20	P	No defects observed
21	P	No defects observed
22	P	No defects observed
23	P	No defects observed
24	P	No defects observed
25	P	No defects observed

O = Overheated
U = Underheated
P = Properly Heated

Table 18. Peel Pull Test Without Sleeve Test Results (Sheet 1 of 2)

Specimen No.	Voltage Drop (mv)	Strength (kg)	Strength (lb)	Remarks
1	2.45	3.63	8.0	Pulled shield apart
2*	2.36			
3	2.36	3.40	7.5	Pigtail peeled
4	2.35	1.91	4.2	Pulled solder from shield
5	2.39	2.90	6.4	Pigtail peeled
6	2.36	3.76	8.3	Pigtail peeled
7	2.43	3.63	8.0	Partial separation of solder & shield
8*	2.43			
9	2.33	2.99	6.6	Pigtail peeled
10	2.39	2.18	4.8	Solder separated from shield
11	2.4	1.00	2.2	Separated solder from shield
12	2.39	2.72	6.0	Pigtail peeled
13	2.46	2.86	6.3	Separated solder and shield
14	2.42	3.63	8.0	Pigtail peeled
15*	2.34	2.72	6.0	Pigtail peeled
16*	2.35			
17	2.39	3.9	8.6	Solder separated from shield
18*	2.44			
19	2.4	.91	2.0	Separated solder from shield
20	2.41	2.63	5.8	Separated solder from shield

*Metallurgical Specimen

Table 18. Peel Pull Test Without Sleeve Test Results (Sheet 2 of 2)

Specimen No.	Voltage Drop (mv)	Strength (kg)	Strength (lb)	Remarks
21	2.39	3.08	6.8	Separated solder from shield
22	2.48	2.63	5.8	Pigtail peeled
23	2.43	4.90	10.8	Shield tore up
24	2.45	2.40	5.3	Separated solder from shield
25	2.36	1.00	2.2	Separated solder from shield

Table 19. Flux Residue, Corrosion Test Visual Inspection

Specimen No.	Heat	Remarks
1	P	No defects observed
2	P	No defects observed
3	P	No defects observed
4	P	No defects observed
5	P	No defects observed
6	P	No defects observed
7	P	No defects observed
8	P	No defects observed
9	P	No defects observed
10	P	No defects observed
11	P	No defects observed
12	P	Braid strand crosswise
13	P	Narrow fillet
14	P	No defects observed
15	P	No defects observed
16	P	No defects observed
17	P	Braid strand crosswise
18	P	No defects observed
19	P	No defects observed
20	P	No defects observed
21	P	No defects observed
22	P	No defects observed
23	P	No defects osbserved
24	P	No defects observed
25	P	No defects observed

O = Overheated
U = Underheated
P = Properly Heated

Table 20. Flux Residue, Corrosion Test (Test Results)

Specimen No.	Voltage Drop (mv)
1	2.6
2	2.64
3	2.62
4	2.5
5	2.51
6	2.54
7	2.56
8	2.54
9	2.56
10	2.56
11	2.57
12	2.63
13	2.52
14	2.54
15	2.57
16	2.47
17	2.2
18	2.67
19	2.5
20	2.63
21	2.5
22	2.55
23	2.6
24	2.6
25	2.55

Table 21. Dielectric Strength Test Visual Inspection

Specimen No.	Heat	Remarks
1	P	No defects noted
2	P	No defects noted
3	P	No defects noted
4	P	No defects noted
5	O	Poor wetting action on shield

O = Overheated
U = Underheated
P = Properly heated

Table 22. Dielectric Strength Test (Test Results)

Specimen No.	Voltage Drop (mv)	Breakdown Voltage			Remarks
		Conductor (kv)	Insulation	Sleeve (kv)	
1	2.45	7	Arced 3/4 inch from sleeve	4	Arced from foil to end of conductor
2	2.43	8	Arced 1/4 inch from sleeve	7	Arced from foil to pigtail
3	2.44	7	Arced at opposite end of specimen from sleeve	5	Arced from foil through end of sleeve
4	2.46	8	Arced at end of sleeve	6	Arced from foil to end of conductor
5	2.47	8	Arced at end of sleeve	6	Arced from foil through end of sleeve

Table 23. Types of Specimen Tested

No. of Specimens	Wire Type		Specimen Type
	Conductor	Pigtail (lead)	
14	Three conductor AWG20 INICS-LTM-1932-NIC-SK-JIM	AWG20 LTM 1932-NIC-SK	Shield termination
4	AWG22 Alloy 63 Surok insulated stranded wire shielded and jacketed	One conductor AWG20 Alloy 63, Surok insulated stranded wire	Shield termination
15	Single conductor AWG20 INICS-LTM-1932 NIC-SK-JIM	AWG20 LTM 1932 NIC-SK	Shield termination
4	NA	Single conductor AWG22 Alloy 63, Surok insulated stranded wire	Stub splice 8 wire
11	NA	Single conductor AWG20 LTM 1932 NIC-SK	Stub splice 6 wire
14	NA	Single conductor AWG20 LTM 1932 NIC-SK	Stub splice 2 wire
1	NA	Single conductor AWG22 Alloy 63 Surok insulated stranded wire	Stub splice 2 wire

2

Table 24. Voltage Drop and Pull Strength Tests* (Sheet 1 of 4)

Specimen No.	Voltage Drop (mv)	Strength (kg)	Strength (lb)	Remarks
	Shield Termination Three Conductor Nickel Plated Copper AWG 20			
1	2.0	18.14	40.0	Pigtail broke
2	2.0	15.88	35.0	Pigtail broke
3	2.05	16.56	36.5	Pigtail broke
4	2.01	16.96	37.4	Pigtail broke
5	2.0	17.92	39.5	Pigtail broke
6**	2.04			
7	2.09	15.88	35.0	Pulled out part of braid
8	2.04	17.69	39.0	Pigtail broke
9	1.92	16.33	36.0	Solder joint broke
10	2.01	17.92	39.5	Pigtail broke
11	2.05	17.24	38.0	Pigtail broke
12	2.15	14.51	32.0	Solder joint broke
13	1.95	17.24	38.0	Pigtail broke
14**	1.91			
	Alloy 63 AWG 22			
15	3.0	17.69	39.0	Solder joint broke
16	3.01	19.41	42.8	Pigtail broke
17	2.93	18.60	41.0	Pigtail broke
18	2.93	18.87	41.6	Pigtail broke

Table 24. Voltage Drop and Pull Strength Tests* (Sheet 2 of 4)

Specimen No.	Voltage Drop (mv)	Strength (kg)	Strength (lb)	Remarks
	Nickel Plated Copper Size AWG 20			
19	2.56	17.69	39.0	Pigtail broke
20	2.45	17.60	38.8	Pigtail broke
21	2.3	17.60	38.8	Pigtail broke
22	2.42	17.23	38.0	Pigtail broke
23	2.4	16.23	35.8	Pigtail broke
24	2.46	17.23	38.0	Pigtail broke
25	2.36	17.69	39.0	Pigtail broke
26	2.42	17.69	39.0	Pigtail broke
27	2.42	17.69	39.0	Pigtail broke
28	2.41	18.14	40.0	Broken shield
29	2.37	17.69	39.0	Pigtail broke
30	2.4	17.23	38.0	Pigtail broke
31	2.42	17.60	38.8	Broken shield
32	2.36	17.69	39.0	Broken shield
33	2.33	17.78	39.2	Pigtail broke
	Alloy 63 Stub Splice 8 Wire			
34	4.18	17.23	38.0	Pigtail broke
35	4.17	16.78	37.0	Center wire broke
36	4.51	15.88	35.0	Wire broke
37	4.4	15.42	34.0	Center wire broke

Table 24. Voltage Drop and Pull Strength Tests* (Sheet 3 of 4)

Specimen No.	Voltage Drop (mv)	Strength (kg)	Strength (lb)	Remarks
	6 Wire Stub Splice AWG 20 Nickel Plated Copper			
38	2.40	7.26	16.0	Broken lead
39	2.2	16.33	36.0	Lead broke
40	2.40	15.42	34.0	Lead pulled out of ferrule
41	2.35	15.42	34.0	Broken wire
42	2.35	16.33	36.0	Broken wire
43	2.26	14.51	32.0	Broken wire
44	2.25	15.88	35.0	Broken wire
45	2.25	16.33	36.0	Broken wire
46	2.14	15.88	35.0	Broken wire
47	2.34	16.33	36.0	Pulled wire out of ferrule
48	2.36	15.88	35.0	Broken wire
	2 Wire Stub Splice 20 AWG Nickel Clad Copper			
49	2.07	17.23	38.0	Broken wire
50	2.06	15.88	35.0	Broken wire
51	2.1	15.88	35.0	Broken wire
52	2.13	14.51	32.0	Broken wire
53	2.05	15.42	34.0	Broken wire
54	2.06	17.23	38.0	Broken wire
55	1.9	17.15	37.8	Broken wire
56	2.13	15.88	35.0	Broken wire

Table 24. Voltage Drop and Pull Strength Tests* (Sheet 4 of 4)

Specimen No.	Voltage Drop (mv)	Strength (kg)	Strength (lb)	Remarks
57	2.07	16.78	37.0	Broken wire
58	2.07	15.88	35.0	Broken wire
59	2.15	15.42	34.0	Broken wire
60	2.1	16.78	37.0	Broken wire
61	2.22	16.56	36.5	Broken wire
62	2.09	16.33	36.0	Broken wire
	2 Wire Stub Splice Alloy 63 AWG 22			
63	4.27	18.60	41.0	Broken wire

*Specimens supplied by Manufacturing and Engineering Laboratory
**Cross sectioned.

Table 25. Solder Sleeve Connections Using Prefluxed Shield Visual Inspection (Sheet 1 of 2)

Specimen No.	Heat	Remarks
1	P	No defects noted
2	P	No defects noted
3	P	No defects noted
4	P	No defects noted
5	P	Braid strand protruding sleeve
6	P	No defects noted
7	P	No defects noted
8	P	No defects noted
9	P	Solder leaked from sleeve
10	P	No defects noted
11	P	No defects noted
12	P	No defects noted
13	P	No defects noted
14	P	No defects noted
15	P	No defects noted
16	P	No defects noted
17	P	No defects noted
18	P	No defects noted
19	P	No defects noted
20	P	No defects noted
21	P	No defects noted
22	P	No defects noted
23	P	No defects noted

O = Overheated
U = Underheated
P = Properly Heated

Table 25. Solder Sleeve Connections Using Prefluxed Shield Visual Inspection (Sheet 2 of 2)

Specimen No.	Heat	Remarks
24*	P	
25*	P	
26	P	Tested for chloride ions
27	P	Tested for chloride ions

O = Overheated
U = Underheated
P = Properly Heated

*Metallurgical sections

Table 26. Prefluxed Shield Test Results

Specimen No.	Voltage Drop (mv)	Strength (kg)	Strength (lb)	Remarks
1	2.46	4.76	10.5	Broken shield
2	2.24	5.00	11.0	Peeled
3	2.26	4.30	9.5	Peeled
4	2.27	5.21	11.5	Peeled
5	2.28	5.44	12.0	Peeled
6	2.31	5.67	12.5	Broken shield
7	2.26	5.44	12.0	Peeled
8	2.26	6.12	13.5	Broken shield
9	2.36	2.95	6.5	Peeled
10	2.36	3.40	7.5	Peeled
11	2.35	5.00	11.0	Peeled
12	2.34	4.76	10.5	Broken shield
13	2.27	3.40	7.5	Peeled
14	2.32	5.44	12.0	Peeled
15	2.33	4.54	10.0	Broken shield
16	2.25	5.90	13.0	Peeled
17	2.29	5.67	12.5	Broken shield
18	2.26	6.35	14.0	Peeled
19	2.30	3.18	7.0	Peeled
20	2.29	3.36	7.4	Peeled
21	2.27	4.30	9.5	Peeled
22	2.23	2.95	6.5	Peeled
23	2.23	5.21	11.5	Peeled

Table 27. Heat Time Versus Peel Strength Test (Test Results) (Sheet 1 of 4)

Specimen Group No.	Time (sec)	Strength (kg)	Strength (lb)	Strength Average (kg)	Strength Average (lb)
		3.48	7.0		
		1.36	3.0		
		3.54	7.8		
		0.68	1.5		
1	12	0.91	2.0	1.85	4.07
		1.59	3.5		
		1.72	3.8		
		0.59	1.3		
		3.54	7.8		
		1.36	3.0		
		0.91	2.0		
		0.59	1.3		
		3.18	7.0		
		3.40	7.5		
2	14	4.76	10.5	2.30	5.06
		1.81	4.0		
		3.54	7.8		
		3.72	8.2		
		1.91	4.2		
		3.63	8.0		
		1.00	2.2		
		3.18	7.0		
		3.54	7.8		
		3.72	8.2		
		5.22	11.5		
3	16	3.63	8.0	3.44	7.59
		3.81	8.4		
		3.81	8.4		
		3.72	8.2		
		2.81	6.2		

Table 27. Heat Time Versus Peel Strength Test (Test Results) (Sheet 2 of 4)

Specimen Group No.	Time (sec)	Strength (kg)	Strength (lb)	Strength Average (kg)	Strength Average (lb)
4	18	3.63 3.27 1.00 2.49 3.18 2.18 2.95 2.95 4.40 3.76	8.0 7.2 2.2 5.5 7.0 4.8 6.5 6.5 9.7 8.3	2.98	6.57
5	20	2.36 3.08 3.76 3.76 4.99 4.08 4.31 4.53 4.08 4.08	5.2 6.8 8.3 8.3 11.0 9.0 9.5 10.0 9.0 9.0	3.91	8.61
6	22	5.22 4.31 4.99 4.99 5.99 2.95 4.31 4.08 5.44 3.86	11.5 9.5 11.0 11.0 13.2 6.5 9.5 9.0 12.0 8.5	4.61	10.17

Table 27. Heat Time Versus Peel Strength Test (Test Results) (Sheet 3 of 4)

Specimen Group No.	Time (sec)	Strength (kg)	Strength (lb)	Strength Average (kg)	Strength Average (lb)
		4.31	9.5		
		4.99	11.0		
		4.53	10.0		
		3.99	8.8		
7	24	4.53	10.0	4.70	10.36
		4.90	10.8		
		4.90	10.8		
		5.90	13.0		
		4.45	9.8		
		4.49	9.9		
		4.99	11.0		
		4.53	10.0		
		4.99	11.0		
		4.53	10.0		
8	26	4.31	9.5	4.59	10.11
		5.44	12.0		
		3.56	7.4		
		4.31	9.5		
		5.58	12.3		
		3.81	8.4		
		5.35	11.8		
		5.35	11.8		
		5.13	11.3		
		4.08	9.0		
9	28	6.12	13.5	4.90	10.8
		5.35	11.8		
		4.45	9.8		
		5.08	11.2		
		4.26	9.4		
		3.81	8.4		

Table 27. Heat Time Versus Peel Strength Test (Test Results) (Sheet 4 of 4)

Specimen Group No.	Time (sec)	Strength		Strength Average	
		(kg)	(lb)	(kg)	(lb)
		6.49	14.3		
		5.22	11.5		
		4.53	10.0		
		5.26	11.6		
10	30	3.86	8.5	5.15	11.35
		4.81	10.6		
		5.17	11.4		
		4.99	11.0		
		6.08	13.4		
		5.08	11.2		
		0.726	1.6		
		3.40	7.5		
		4.08	9.0		
		5.22	11.5		
11	32	3.54	7.8	3.99	8.8
		5.44	12.0		
		4.76	10.4		
		4.08	9.0		
		3.63	8.0		
12	18	*			
	24	*			

*Metallurgical Specimens

December 1, 1967 IN-R-QUAL-67-10

APPROVAL

EVALUATION TESTING OF THERMOFIT SOLDER SLEEVES

The information in this report has been reviewed for security classification. Review of any information concerning Department of Defense or Atomic Energy Commission programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.

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